CROSS TALK

►**OBIT** . . . The death of Harry Diamond, at the height of his career, is a severe loss to the profession and to the Bureau of Standards, where he headed the Electronics Division. His work on radio range beacons, the instrument landing system, the radiosonde and the proximity fuze, are outstanding contributions to aviation and military science. They are matched by an equal contribution to the training of young radio scientists, many of whom received their first inspiration from Mr. Diamond. He saw electronics clear and he saw it whole. One of his last speeches contained a breakdown of the field of electronics:

This was his business; he served it well:

(1) Radio communication and broadcasting, including television and facsimile.

(2) Electronic ordnance, including radar fire control, electronic controls for guided missiles, proximity fuze, and electronic controls for underwater torpedoes.

(3) Radio navigational aids, including radar, loran, and other sea and air navigational aids.

(4) Electronic power conversion, including dielectric and inductive heating.

(5) Electronic instrumentation and controls, including special instruments for physical, chemical, medical and biological research and practice, and the general concept of the servomechanism.

(6) Electronic devices for mathematical computation.

►**TELE-QRN** . . . For years the fight against man-made interference has been conducted by the men of radio against the great outside world, the non-radio domain of electric shavers, telephone dials, ignition systems, and similar impulsive characters. More lately, the battle has assumed the character of a civil war.

In television engineering, at least, the arms of brothers are raised in conflict. A television set lives on impulses, at high level in the scanning and video-amplifier circuits, and these pulses, uncontrolled, raise lots of hob with other radio and television sets in the vicinity. An RMA Committee has given wide circulation to this fact, and urged that adequate shielding be employed to cure the interference. But most sets employing magnetic scanning (the majority at present) are still very noisy out to 10 or 20 feet, much more than the thickness of the wall between apartments. This nuisance, if unabated, threatens to unsell a lot of equipment. Like the oscillator radiation problem, it remains a solvable problem on which not enough money and manpower have yet been spent.

A related miscellany is a letter from the city fathers of Garden City, N. Y., sent to all residents, asking them kindly to refrain from erecting television antennas on the roofs of that as-yet-unspoiled village. Seems they have gone so far as to ask experts, who tell them that the flat terrain of Long Island, close to New York, with no high buildings in the vicinity, is ideal for aerials inside attics.

►**SEMICONS** . . . From audion to orthicon (not forgetting pliotron, kenotron, thyratron, and ignitron) it has been customary to coin names for the vacuum-tube family ending in "on". Now comes another family, practitioners of the art without benefit of vacuum. These are the solid-state cousins, the crystal brethren, the germanium, silicon, copper oxide, selenium boys. For years these crystals have rectified, detected, responded to light and to heat. Now, with the coming of the transistor (described in this issue), they amplify. Seems like the country cousins ought to have a name.

Since these crystals are electronic by occupation, if not by constitution, we beg leave to suggest a name in the vacuum-tube tradition. To wit, semicon: a device employing a semiconducting material in the solid state, through which flows a current capable of being varied by external physical influences. The crystal detector current varies with the direction of the applied potential; it rectifies. The barrier-layer photocell current responds to light, the thermistor current to heat. The transistor current responds to the magnitude of an applied voltage; it amplifies. Respectable brethren, these semicons, and welcome.

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Dr. William Shockley, who directed the research, Dr. John Bardeen, who developed the theory, and Dr. W. H. Brattain, whose experiment verified it discuss physics of Transistor

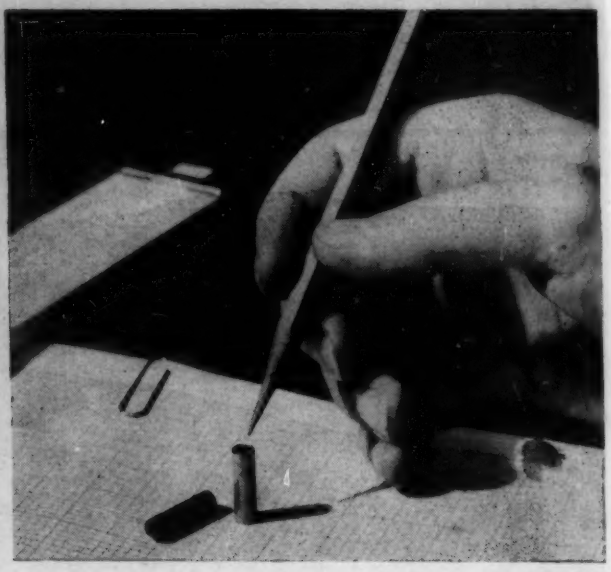

FIG. 1—Because of its simplicity the Transistor is even smaller than most subminiature vacuum tubes. The amplifier itself can be no larger than its associated coupling components

The TRANSISTOR— A Crystal Triode

Germanium crystal with two cat-whisker contacts has characteristics of grounded-grid triode amplifier, provides 20 db gain, 25 milliwatts output at frequencies up to 10 megacycles. It will replace vacuum tubes in many applications and open new fields for electronics

A NEW DEVICE, operating on an entirely new principle and capable of many functions of the electronic vacuum tube, but having neither an evacuated envelope nor a hot cathode, was announced early in July by scientists of the Bell Telephone Laboratories. Known as a TRANSISTOR (TRANSfer reSISTOR), the device is essentially a triode form of the well known germanium crystal diode.

In its present experimental form the Transistor is a metal cylinder 3/16 inch in diameter and $\frac{1}{2}$ inch long, as shown in Fig. 1. Inside the cylinder, Fig. 2A, is a block of germanium soldered to a metal disc to which it makes low resistance contact and that grounds it to the cylinder. Two 2-mil tungsten wires make contact with the upper face of the germanium at points about 0.002 inch apart.

An input signal, Fig. 2B, in series with a small positive bias voltage, is applied between the grounded face and the input cat whisker (emitter). A large negative bias voltage is applied between ground and the output (collector) point contact. The output signal appears across a load resistor in series with the negative bias. In this manner a power gain of 100 (20 db) is obtained between input and output of a Transistor. The terminal characteristics of an experimental Transistor are shown in Fig. 2C (see the *Phys. Rev.* p 230, July 15, 1948.) This is an early unit having a gain of about 15 db. The characteristics are typical of later units having an average gain of 20 db.

Because of its unique properties, the Transistor is destined to have far-reaching effects on the technology of electronics and will undoubtedly replace conventional electron tubes in a wide range of applications. The Transistor requires no heater or filament power and uses the power supplied by its bias sources with high efficiency. Under typical operating conditions it draws only 0.1 watt from the bias sources (about a tenth the power consumed by a flashlight bulb) and delivers 25 milliwatts of useful output, thus having an overall efficiency

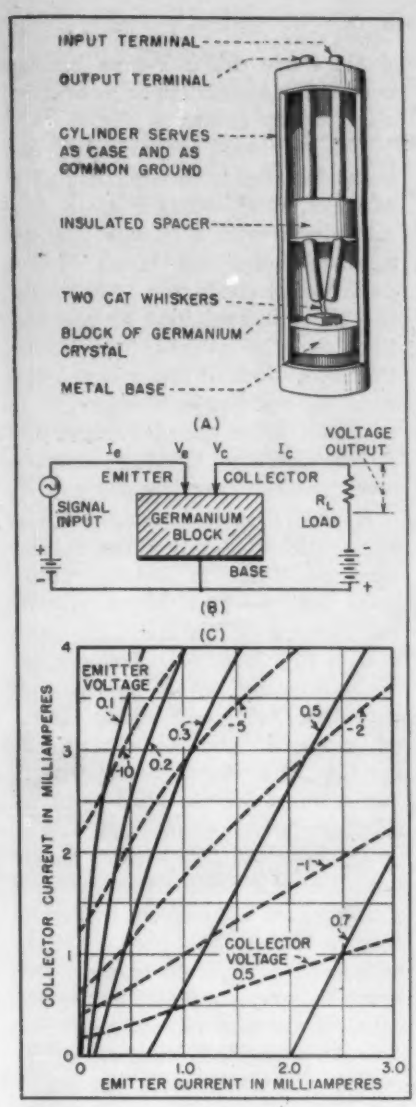

FIG. 2—Crysal triode (A) consists of two cat whiskers connected to separate input and output circuits (B) to give characteristics (C) that produce high amplification

of 25 percent.

The Transistor is smaller than a subminiature vacuum tube. It seems likely to have a useful life of many thousands of hours because of its simple, sturdy construction. Where portability and low battery drain are essential, as in hearing aids and personalized radios, the Transistor appears ideal. In equipment using large numbers of amplifiers, large-scale computers being an extreme example, the absence of a heater makes it possible to place many Transistors in confined space without creating difficulties in heat dissipation.

Although cost factors have not been thoroughly explored, Transistors should be no more costly to manufacture at present than the 1N34 (high back-voltage) germanium diode, which lists for replacement at $1.20 and is obtainable in large lots by equipment manufacturers at $0.53 apiece. These prices are slightly higher than the prices of a corresponding vacuum diode (6H6). However, present costs of crystal diodes are not representative of inherent costs. The industry has spent about 40 years mechanizing production of vacuum tubes and has written off engineering and plant costs over that time. If crystal devices (diodes and Transistors) prove as successful in practice as they now appear to be, they too will be put into mechanized production and their cost reduced. Ultimately they should be cheaper than comparable vacuum tubes because of their simplicity and because they do not require evacuation, which is the most difficult step in producing vacuum tubes.

There are limitations to the use of Transistors in their present state of development. The power output is restricted to about 25 milliwatts per unit, or 50 mw from a push-pull stage. A Transistor capable of developing several watts output does not seem feasible at present. Parallel operation of two or more units is possible, however, and could be used to increase the power to a load several fold. The upper frequency of operation is limited to about 10 megacycles by transit time within the germanium. Thus the Transistor is at present useful at audio, video, and the lower radio frequencies, but is unsuited to vhf and uhf applications. Furthermore, the noise generated within a Transistor is appreciably greater than that produced in vacuum triodes.

If the requirements of an application for which the properties of Transistors are suitable justify their cost when they first become commercially available, there remains a temporary obstacle to their immediate use, namely engineering this new device into the circuit. One of the principle problems requiring development is matching the input and output impedances of the Transistor to the circuit. The input impedance of the Transistor is low because the bias in the input circuit causes current to flow in the forward direction through the point contact of the emitter. On the other hand, the output impedance of the Transistor is about a hundred times higher than the input impedance because its bias causes current to flow in the reverse direction through the point contact of the collector. These impedance levels are the opposite of those for vacuum tubes and require a new approach to the coupling circuits between amplifier stages. Intensive work on this problem is underway. The Transistor thus opens new fields for clever design and inventive talent.

Illustrative Applications

In announcing the Transistor, BTL scientists demonstrated several typical electronic devices in which it was used. A booster amplifier for telephony illustrated its application to voice-frequency amplification. A similar video amplifier was also demonstrated. Its low power-supply drain makes it suitable for telephone and television repeater service. In fact, it requires no more power than that usually available at a subscriber's set from the central office batteries that are connected to the line. Use of a Transistor as an oscillator showed the versatility of the unit. Use in a radio receiver for the standard broadcast band illustrated its practicality.

The radio receiver contained no tubes. It consisted of a broad-band r-f amplifier, a tuned r-f stage, local oscillator, mixer, three stages of i-f, second detector, and four stages of a-f amplification, the last being push-pull. A total of 11 Transistors were used in the amplifier stages, with 2 germanium diodes for the mixer and detector stages, and 2 selenium rectifiers for the power supply. The receiver brought in local stations, delivering 25 mw of audio power to its loudspeaker.

At low power levels crystal diodes and triodes, in conjunction with printed circuits, make possible the extension of electronic techniques. Existing equipment can be made more compact. Transistors, having no filament, are operative the instant power is applied.

Research Background

Research work in semiconductor materials began at least 24 years ago. Germanium and other semi-

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conductors have been used as rectifiers because of their unilateral conductivity. These employ a single point contact; the input and output circuits are not separated. The two-contact arrangement is the practical outcome of a long program of scientific research on semiconductors.

Although investigation of semiconductors at BTL dates back a number of years, with the end of the war a concentrated basic research program was undertaken. Groups in the Physics Department were reorganized. Additional personnel were taken on, particularly theoretical specialists. The groups consisted of paper-work men and laboratory experimentalists who could pass problems from office desk to lab bench and back as the program unfolded. The fact that pure research paid off relatively quickly, in so spectacular a way, is testimony to the ability of the men who carried out the program and to the facilities with which they worked.

The group on semiconductors, led by William Shockley, one of this country's leading solid-state physicists, was seeking answers to three basic questions: (1) physically, what is a semiconductor, (2) how does its physical nature produce its observed properties, and (3) how does the fabrication and processing of the material affect its physical nature? Among the semiconductors studied were silicon, copper oxide, and germanium.

A great deal of empirical information had been amassed on these substances during their use, particularly as detectors in microwave equipment ("Crystal Rectifiers," H. C. Torrey and C. A. Whitmer, McGraw-Hill, 1948). In particular it was known that their resistivities were determined chiefly by impurities, and furthermore that their resistivities could be varied over wide ranges by applying various external influences (light in the case of photocells, electric potential in the case of rectifiers and detectors, or temperature in the case of Thermistors).

Theory of Conduction

Modern physics has developed a detailed concept of the construction of matter and consequently an understanding of the mechanism of conduction. In metals there is approximately one free electron that can be used for carrying current for every atom; in insulators there are practically no free electrons. By free electrons is meant electrons so loosely associated with their atoms that they can easily be induced to move to adjacent atoms.

In semiconductors there is only about one current-carrying electron for every millions atoms, but this number of carriers can be varied 1,000-fold by changing the physical environment of the material. Such a change in the number of carriers is effectively a change in the resistance of the material. For example, light falling on a barrier layer changes its resistance. Alternating voltage applied to a selenium rectifier or a germanium diode changes its resistance so that current flows predominantly in one direction. Likewise, a high potential applied externally (without making contact) to a semiconductor should change its resistivity. Using a sheet of germanium as one plate of a capacitor, Shockley and his colleagues measured the change in resistance produced by changing the voltage across the capacitor. The change in resistance was much smaller than anticipated in the light of prevailing theory. Conclusion: something wrong with theory. So John Bardeen, a theoretical physicist in the group, devised a theory of surface states that would account for the measured change as well for older known effects unexplained by previous theories.

To review the old theory for a moment, it was known that conduction in semiconductors could take place by two mechanisms, operating either separately or simultaneously. In some types of semiconductors the electrons, as usual, moved under the influence of applied voltages and thus provided a current flow. Such semiconductors are called N-type because conduction is by negative (electron) charges. In other types of semiconductors, in which there is a deficiency of electrons, the current flow consists of the movement of virtual positive charges (images of electrons) that are actually empty places from which electrons have been removed. Such semiconductors are called P-type because conduction appears to be by positive charges, are shown in Fig. 3.

The two types of conduction had been identified with impurities. For example, as shown in Fig. 3B, silicon alloyed with a minute percentage of phosphorus is an N-type (electronic) conductor. Physically, the effect is explained by the fact that phosphorus has five valence electrons. Four of these form bonds with the four valence electrons in a silicon atom (thus binding the atoms together), leaving one electron free for carrying current.

If the impurity is boron (Fig. 3C), which has only three valence electrons, there is one incomplete bond between each boron and its neighboring silicon atom, leaving a hole in the structure. Because the percentage of boron impurity is very low, not many silicon atoms are so bound. Hence the hole in the bond of one silicon atom with a boron atom can be filled with an electron from an adjacent silicon atom under the influence of an external electric field. However, this action leaves a hole from which the electron came. This hole is free to be passed from atom to atom and hence to carry current. Whereas a negative electron will migrate from a negative region toward a positive region when voltage is applied, a hole will migrate from a positive region to a negative one. (In P-type —hole—conductors the electrons would have no place to go if it were not for the hole, so, although the electrons do move when current flows, it is the presence of the hole that makes their motion possible. Thus, to physicists, conduction is by (owing to the presence of) holes. Such action takes place in germanium.

The new theory suggested new experiments, which, when performed, called for refinements in the theory. While W. H. Brattain and John Bardeen were following up the consequences of the refined theory of surface states they invented the Transistor. With it they discovered a surface layer having peculiar characteristics.

To account for these characteristics, they postulated and later showed by experiment that there is a thin layer of electrons at the

surface of germanium. This surface layer would prevent the penetration into the body of the semiconductor of an externally applied field and thus account for the smallness of the changes in resistance observed in the capacitor experiment. The field created by these surface electrons causes the formation of holes in the adjacent material, and these holes conduct current. The conducting layer may be caused by an excess of impurities near the surface such as boron that accept electrons into bonds and thus create holes, or by a space-charge barrier layer. Between this P-type layer and the N-interior is a rectifying barrier.

When a single point contact is made, the surface layer determines the conductivity for reverse currents or small forward currents. For large forward currents there is an increase in the concentration of carriers (electrons and holes). In either case (forward or reverse current) a large part of the current is carried by the surface conducting layer within an area of interaction very close to the point. Within this area the conductivity, which is mainly by holes, is much greater than elsewhere in the semiconductor. The second point contact for the Transistor is added within this area of interaction.

Transistor Characteristics

In a Transistor, the positive point contact causes the release of holes in the surface layer of the germanium, which is prepared in a similar manner to a high back-voltage rectifier. These holes spread away from the point, flowing in all directions along the surface (but not into the body of the semiconductor). The holes reach the other contact point 0.005 cm away, in less than a ten-millionth of a second. This is the transit time that limits present performance to frequencies below about ten megacycles. From this observation, it is estimated that the holes travel at the order of 100,000 centimeters per second. Higher applied potentials and smaller spacings, as used in vacuum tubes to increase high-frequency performance, may reduce this transit time. That there are holes capable of moving from 10 to 100 times this speed is known from estimates of their thermal velocities.

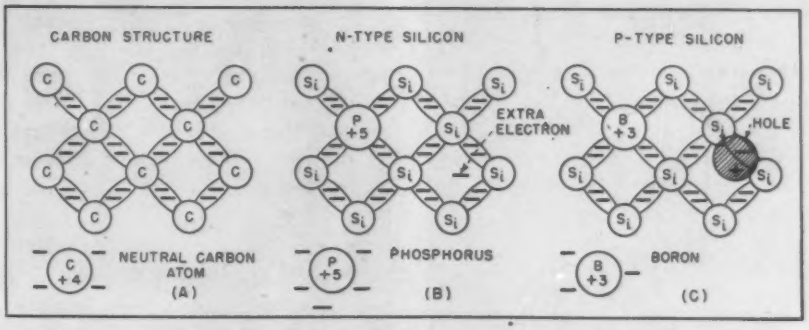

FIG. 3—Conduction within a semiconductor depends on the interatomic bonds formed by the electrons. Current flow in a pure semiconductor is difficult to produce (A). If an impurity having an excess electron (B) is added then that electron can carry current. On the other hand, if the impurity lacks the required number of electrons for the bonds (C) the hole thus created also makes conduction possible

The negative bias applied to the collector causes a very small current to flow from the germanium in the absence of hole conduction produced by the emitter. When the positive bias is applied to the input, however, holes are attracted to the output point contact, which is biased negatively, and these are absorbed, thus increasing the current in the output circuit. Variations in the input current change the number of holes released toward the collector and thus vary the output current proportionately. The Transistor circuit thus closely resembles a grounded-grid triode circuit.

In a grounded-grid vacuum triode the current from the cathode is controlled chiefly by the potential between it and the grid (ground); the plate potential has little effect. In the Transistor the positive bias (about 1 volt) of the emitter (cathode) causes a small current to flow into the semiconductor. The negative bias (up to 50 volts) of the collector (anode) is made large enough so that it withdraws about the same current (a few milliamperes) from the semiconductor. While the collector is a poor emitter of electrons, it is a good collector of holes. A variation of the number of holes in the surface around the two point contacts is produced by changes in the input voltage of the emitter. This variation changes the current (carried by holes) to the collector by a factor of from one to two times the change in emitter current, depending on the operating bias. Furthermore, this change in current flows in the high impedance of the output circuit, of the order of 10,000 to 100,000 ohms. The voltage change produced in this high-impedance circuit by the change in current is thus proportionally large, of the same order of magnitude relative to the signal voltage input as the ratio of reverse to forward impedance of the point contact. There is a corresponding power amplification of the signal.

Because the output circuit can influence the input circuit only by electronic conduction, for which the surface resistance is high, there is little coupling from output to input, and the circuits, one of low impedance (low power) and one of high impedance (high power), are properly isolated for use in unilateral amplification.

The d-c characteristics of a typical experimental Transistor, Fig. 2C, show the interrelation of the four variables, the two currents and the two voltages. If two are specified the other two are determined. The effect depicted by these characteristics shows that, in addition to the forward amplifying action, the collector current lowers the potential of the surface in the vicinity of the emitter in proportion to the collector current times a constant internal resistance, and thus increases the effective bias on the emitter. This describes the nature of the back coupling that exists. Under certain operating conditions this coupling, which represents positive feedbaek, can cause instability. Thus, although the principle of operation is vastly different, the Transistor has the properties of vacuum tube amplifiers in many respects.—D.G.F. and F.H.R.

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RALPH BOWN
(Bell Labs)

MELVILLE EASTHAM
(General Radio)

DONALD G. FINK
(Electronics)

JTAC Its Purpose and Program

The Joint Technical Advisory Committee, eight engineers appointed by RMA and IRE, has the important job of advising government bodies and industry groups on the wise use and regulation of the radio spectrum

THE CENTRAL PROBLEM of the radio industry is the fact that its domain, the radio spectrum, must be administered and policed by agencies subjected to commercial and political pressures, while the by-laws governing the domain are based on technicalities which cannot be changed by commercial or political argument. In each of the major forms of broadcasting for example, this fundamental conflict has led to an improper use of the spectrum, or to faulty administration of it.

Standard broadcasting, put on an orderly basis first in 1925, has suffered ever since from a channel separation too narrow to permit high-fidelity transmission, and the multiple assignment of frequencies (to approximately 2,000 stations at present) has so congested the spectrum that serious interference is the rule in all but urban areas. Television, ready to start in 1939 on standards not radically different from those now used, was stopped dead in its tracks in 1940 by an intra-industry fight which the FCC was unwilling to referee. Frequency modulation was first assigned a band from 44 to 50 mc, and later moved wholesale to 88–108 mc, to the consternation of broadcasters and set owners alike. Whatever the

JOHN V. L. HOGAN
(Interstate Broadcasting)

EWELL K. JETT
(Baltimore Sun)

HARADEN PRATT
(Mackay Radio)

PHILIP F. SILING
(RCA Frequency Bureau)

DAVID B. SMITH
(Philco)

LAURENCE G. CUMMING
Secretary (IRE)

merits of the arguments in each case, the fact remains the public has suffered from an inadequate understanding of the radio spectrum and its standards of use, on the part of regulating bodies and their advisers.

One of the first attempts to rectify this situation was the formation in 1940 of the National Television System Committee, to advise the FCC on television standards. The success of this effort led to an extension to cover additional classes of radio service. This was the Radio Technical Planning Board, which presented evidence to the FCC on the post-war allocation of frequencies. Other groups, notably the Radio Technical Commission for Aeronautics and similar groups for marine (RTCM) and land-mobile (RTCLM) services have been formed to study the problems of particular services and to recommend standards and allocations for them.

On July 1st, 1948, the RTPB was dissolved, and its panels were absorbed in the committee structures of the RMA and the IRE. This action was based on the realization that the administration of the spectrum could no longer be guided solely by groups devoted to particular services, as were the RTPB

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panels. The competition for additional ether space had reached fever pitch and the FCC despaired of refereeing between panels recommending opposed allocations based on conflicting technical evidence. What was needed was an impartial committee to act as a buffer between the regulating body and the proponents of individual services.

Formation of JTAC

The signal for the formation of such a group came soon after the appointment of Wayne Coy to the chairmanship of the FCC. At the IRE annual convention in March 1948, Mr. Coy pointed to the FCC's need for assistance in arriving at an adequate national allocation of television facilities, and mentioned the needs of other services, notably the land-mobile service, as conflicting factors.

At that time the IRE was considering the formation of a technical committee on spectrum utilization, which would gather evidence on the characteristics of different portions of the spectrum and correlate them with the needs of particular classes of service. This committee was the brainchild of the incoming IRE president, B. E. Shackelford. Acting on Mr. McCoy's request, Shackelford met with W. R. G. Baker, outgoing IRE president and Director of the RMA Engineering Department. Together these men roughed out the plan for a joint IRE-RMA committee to consider problems of spectrum utilization and to assist the FCC as required. The idea was presented to the Boards of Directors of the IRE and RMA, and received their blessing.

Two men were appointed to the committee initially, Philip F. Siling, representing IRE, to serve as the first chairman, and Donald G. Fink, representing RMA, to serve as vice chairman. These men met with a group of interested engineers on May 12th to develop the basic philosophy of the new committee. Based on this discussion a charter was drawn up, amended and finally approved by IRE and RMA June 20th.

The charter, the full text of which is appended here, establishes a committee of eight members, each to serve for two years. While JTAC will find that most of its actions relate to FCC activities, it will assist other government bodies, such as the Interdepartment Radio Advisory Committee, and the Civil Aeronautics Authority, on request, and is also available to industry groups, such as railroad, aviation and marine interests. If the load gets too heavy, JTAC has the power to decide on its own motion what problems it will tackle first.

Established IRE and RMA technical committees will be called on to supply information and make detailed studies for JTAC, and special ad hoc committees may be appointed to do so. Other groups or individuals who may have information will be encouraged to pass it to the JTAC. To this end, notices of problems under consideration will be published regularly in the technical press. JTAC's findings will be available to all who request them.

The basic information collected by JTAC will thus come from informed sources, including recognized specialists in particular fields. JTAC's overriding responsibility will be to sift the information for internal inconsistencies or conflicts, to separate facts from opinions, and to remove commercial bias. To assist in this job, it has the power to appoint technical consultants. Moreover, the JTAC members are chosen as individuals of high professional standing, and are expected to conduct themselves completely outside the sphere of company politics and commercial interest. In fact, it is only by so operating that the JTAC can earn the reputation for complete objectivity, impartiality and accuracy which its charter sets up as a goal.

Television Hearing

The need for the JTAC is underlined by the fact that before its charter was approved and the membership assembled, an urgent request for assistance was presented by the FCC. Early in May, the FCC announced that it would hold a hearing beginning September 20th on the question of utilizing the television frequencies in the region from 475 to 890 mc. These frequencies are currently available for experimentation in improved systems of television, and are reserved for future commercial use when such an improved system is ready for the public. But pressure for additional television channels, plus the demands of other services for space, had forced the FCC to step up its schedule and to inquire, at once, how this space might be used. Accordingly, the FCC requested the JTAC to provide authoritative information on the ways in which these uhf channels might be employed. Questions relating to available equipment and propagation characteristics, were prepared by Commission engineers and were circulated through the JTAC secretariat to the television system committees of the RMA and IRE for detailed study. Reports from these committees, and from other interested groups, were available in mid-August for the critical scrutiny of the JTAC members and their consultants in time for presentation at the hearing in September.

JTAC Charter

The text of the JTAC charter, excepting the preamble and portions relating to administrative procedure, is as follows:

Objective. The JTAC shall obtain and evaluate information of a technical or engineering nature relating to the radio art for the purpose of advising Government bodies and other professional and industrial groups. In obtaining and evaluating such information, the JTAC shall maintain an objective point of view. It is recognized that the advice given may involve integrated professional judgments on many interrelated factors, including economic forces and public policy.

Duties. The duties of the JTAC shall be as follows:

(a) To consult with Government bodies and with other professional and industrial groups to determine what technical information is required to insure the wise use and regulation of radio facilities.

(b) To establish a program of activity and determine priority among the problems selected by it or presented to it in view of the needs of the profession and the public.

(c) To establish outlines of the information required in detailed form. These outlines will be submitted to qualified groups, as hereinafter defined, who shall study the requirements and supply the required information.

(d) To sift and evalute information thus obtained so as to resolve conflicts

of fact, to separate matters of fact from matters of opinion, and to relate the detailed findings to the broad problems presented to it.

(e) To present its findings in a clear and understandable manner to the agencies originally requesting the assistance of the Committee.

(f) To make its findings available to the profession and the public.

(g) To appear as necessary before Government or other parties to interpret the findings of the Committee in the light of other information presented.

Membership. The JTAC shall consist of eight (8) members.

The members shall be chosen on the basis of professional standing, integrity, and competence to deal with the problems to be considered by the Committee. The members shall be chosen from among all qualified engineers irrespective of the organizations to which they belong or the companies by whom they are employed and shall operate without instruction. Half of the members shall be nominated by IRE and half by RMA, and the appointment of all members shall be confirmed by both bodies. None of the members shall receive any regular compensation for services from the National or any State Government. There shall be no alternate members.

Members shall serve for a term of two (2) years, commencing July 1 and terminating June 30. To assist in maintaining the continuity of action of the Committee, half the initial roster of members of the Committee shall be appointed to serve two consecutive terms.

Officers. The officers of the Committee shall be a Chairman, a Vice-Chairman, and a Secretary. The Chairman and Vice-Chairman shall be appointed from among the eight members of the JTAC by the Boards of Directors of the IRE and of the RMA on alternate years and will serve for a term of one year, except as may be otherwise determined by the Boards.

The Secretary shall be a qualified individual appointed by the members of the JTAC and shall serve for a term of one year. The Secretary shall not be a member of the Committee.

Committees and Consultants. The JTAC shall make use of existing committees in the IRE and RMA organizations wherever possible. Where a qualified group does not exist, the JTAC shall appoint ad hoc committees to study and report on particular subjects. Such ad hoc committees shall be disbanded upon completion of their assignments. The Committee shall also make use of qualified sources of information outside the IRE and RMA organizations, including the engineering staffs of Government bodies as well as professional, educational, and industrial groups qualified to assist in its program. Technical consultants may be invited to assist upon occasion, by the Committee as a whole.

JTAC'S FIRST ASSIGNMENT

The FCC hearing scheduled for September 20th, 1948, has the following objectives:

(A) To obtain full information concerning interference to the reception of television stations operating on channels 2 through 13 resulting from adjacent-channel operation of other services, from harmonic radiations, and from man-made noise.

(B) To receive such additional data as may be available since the close of previous hearings (Dockets 6651 and 7896) concerning the propagation characteristics of the band 475 to 890 mc.

(C) To obtain full information concerning the state of development of transmitting and receiving equipment for either monochrome or color television broadcasting, or both, capable of operating in the band 475 to 890 mc.

(D) To obtain full information concerning any proposals for the utilization of the band 475 to 890 mc, or any part thereof, for television broadcasting and the standards to be proposed therefor.

At the request of JTAC, members of the Commission staff prepared the following list of detailed questions:

(1) What is the present state of development of equipment in the band 475 to 890 mc, in regard to (a) transmitters, tubes and components, (b) receivers and components, (c) antennas, transmission lines and related equipment for transmission and reception?

(2) How much experimental work has been undertaken in television systems in this band, with respect to field operation (transmitter hours operated, number and distribution of receivers, and propagation tests) and laboratory work (development of receivers, transmitters and tubes)?

(3) What consideration has been given to the costs of television systems for this band, particularly to the reduction of receiver costs, and the transfer of cost burdens to the transmitter?

(4) What areas of service might be expected in this band, based on the following assumptions: (a) a particular system, using one of the following typical bandwidths: 6 mc, 13 mc, 20 mc; (b) radiated power, available now and expected to be available, say, 10 years in the future, (c) receiver sensitivity, and (d) at each of the following typical frequencies: 475, 600 and 890 mc?

(5) What co-channel and adjacent-channel separations would be appropriate under the assumptions made in item 4, above?

(6) How many channels would be available in the band 475-890 mc, on the assumptions of item 4, above, and how might they be allocated among the 140 metropolitan districts of the United States?

JTAC has transmitted these questions to RMA and IRE committees as well as many other groups, such as NAB and TBA, who may contribute to the store of knowledge. Any reader of *Electronics* who has information on these matters is urged to communicate it at once to the JTAC Secretary, L. G. Cumming, care of the Institute of Radio Engineers, 1 East 79th Street, New York 21, N. Y.

–THE EDITORS.

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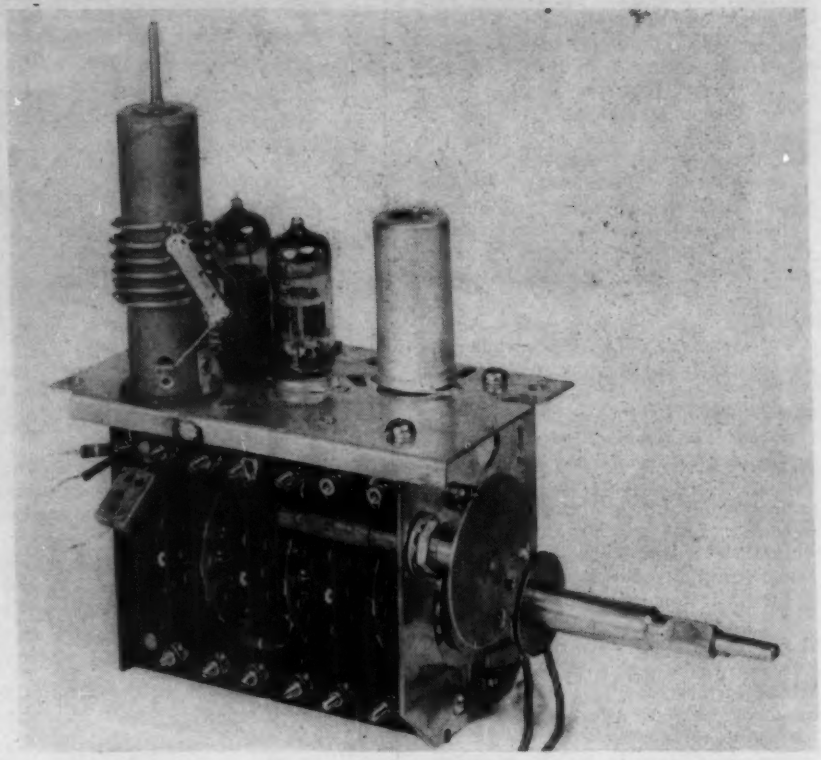


RCA rotary-switch type front end uses transmission lines and push-pull circuits

Television FRONT ENDS

R-f, oscillator and mixer problems are discussed, and current design trends noted. Suggestions for measuring performance are given, and tuning methods at present in use and on the drawing boards are covered in detail

By A. D. SOBEL

Vice-President, Television Engineering
Franklin Airloop Corp.
New York, N. Y.

TELEVISION receiver front-end design is one of the most difficult problems engineers face today. The quality and cost of receivers depends to a large extent upon its solution.

Front ends must have sufficient bandwidth for acceptance of both picture and sound on each of the twelve available channels; almost everything else is optional and at the discretion of the designer.

R-F and Converter

There is, first, the question of gain; this is at present achieved by the inclusion of a stage of r-f amplification.

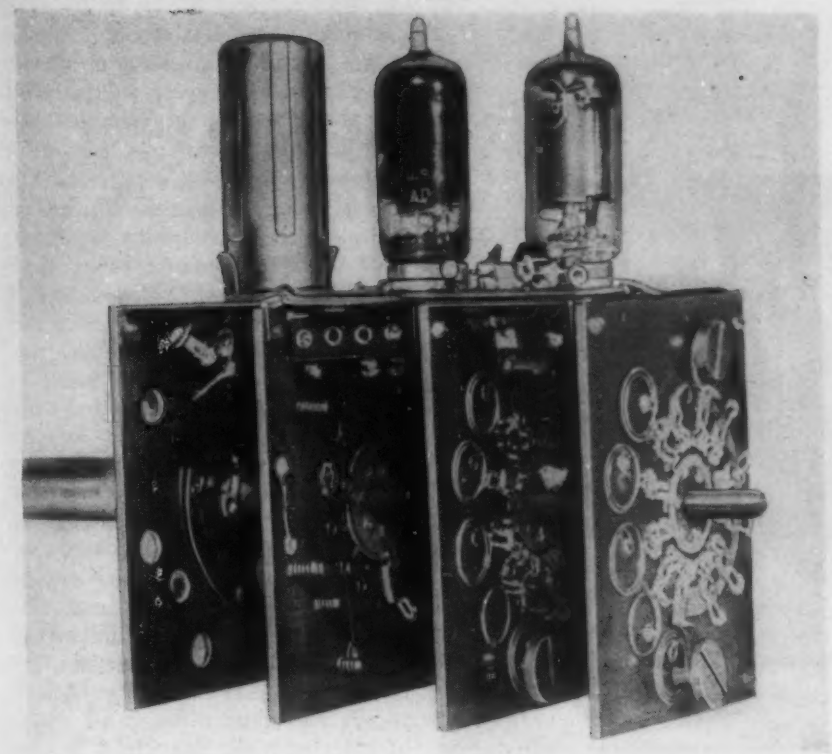
A triode used in the r-f stage gives a better signal-to-noise ratio than a pentode but provides less isolation; there is a possibility of more oscillator voltage passing through the tube and appearing across the antenna terminals. There is, therefore, a trend toward the use of pentodes. The 6BH6 provides adequate gain on the seven highest-frequency channels and also reduces circuit loading.

Theoretically, the greater the number of tuned circuits the better the performance. However, multiple-tuned circuits cannot always be used due to mechanical design considerations and cost, so either grid or plate-circuit tuning is currently employed. Where grid tuning is used, separate antenna coils must be provided for each channel, with the disadvantage that more switch points are needed. Where plate tuning is used the transmission line must be fed into the grid and cathode of the r-f tube, inasmuch as an input circuit balanced for both signal and noise is essential.

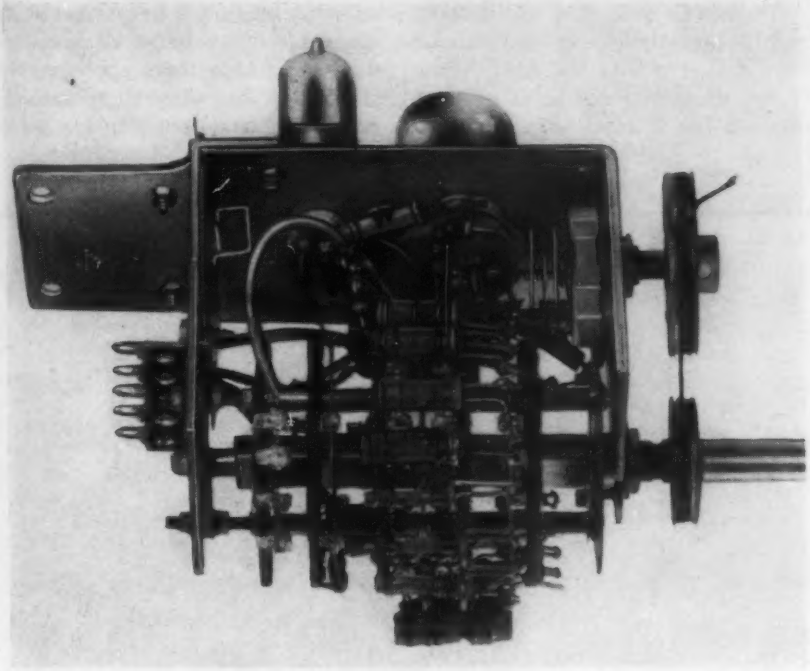
A gain of 6 db is considered satisfactory at the present time for the r-f stage of a television receiver designed for use in the average location. An image-rejection ratio of 40 db can readily be maintained on all channels.

Conversion can be achieved with a triode, pentode, diode, or even a crystal. The 6AG5 pentode performs well as a converter. The oscillator circuit must be chosen carefully; a plate circuit grounded with respect to r-f, with a floating cathode and tuned grid, is probably the easiest to use as there is only one switch point involved.

Some sort of vernier appears to be essential, unless automatic frequency control is incorporated into the design. This is not too difficult to add if a dual triode such as the 12AT7 is used. One half of the tube functions as the oscillator and the other half is used as a reactance



Franklin rotary-switch assembly with die-stamped transmission lines



GE rotary-switch arrangement has conventional inductances

tube. Control voltage is taken from the discriminator or ratio detector in the sound i-f section of the receiver.

An excellent and recommended way to make front-end gain measurements is to figure gain to converter plate, on the basis of gain per 1,000 ohms of converter plate load.

Possibly the greatest drawback today in making accurate measurements is mismatch due to the feeding of a signal from an unbalanced signal generator or sweeper into the balanced input circuit of a receiver.

Measurements

To observe and adjust r-f gain, bandwidth, and coupling, the author feeds a suitable sweeper into the antenna terminals through a correct match for 300 ohms. The output is taken at the converter grid or, better still, at its screen, and connected to an oscilloscope. If the inductances are correct for the different channels a curve can be observed on the oscilloscope screen and frequency markers inserted. Coupling can be adjusted while observing the curve on the oscilloscope.

Drift measurements on a front-end unit should never be made in the open. The unit should be installed on the chassis with which it is to be used and in the cabinet in which the chassis is to be placed. The proper temperature-coefficient capacitors can then be incorporated into the design to counteract the effects of heating.

In designing a tuner the most unexpected conditions are encountered at frequencies between 50 and 250 megacycles. All sorts of resonances can be expected. These frequently manifest themselves as absorption circuits, cutting gain or actually blotting a frequency out entirely. An oscillator may refuse to operate entirely at certain frequencies. Probably the worst offenders in this respect are heater chokes which, with their by-pass capacitors, often resonate in the television band. Switch shafts and plates, frameworks, wiring, and other innocent-looking items also give trouble.

Tuning Methods

There are several methods of tuning television receiver head ends, and sometimes they are used in combination. Typical methods are enumerated in the following paragraphs.

Rotary Switch. The rotary switch has met the needs of radio design engineers for nearly twenty years. It has successfully been applied to

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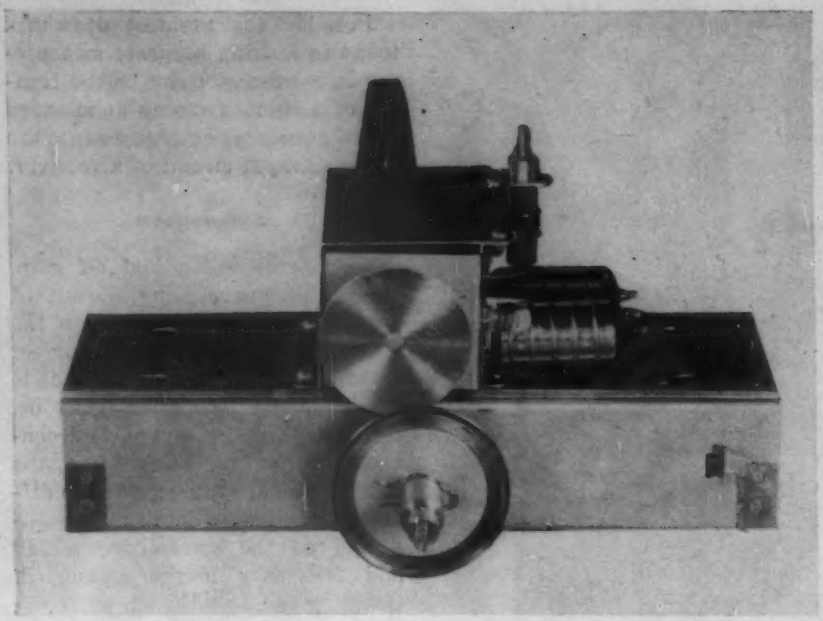


Hazeltine sliding turret has individual inductances

television, sometimes using conventional inductances and sometimes resonant transmission lines.

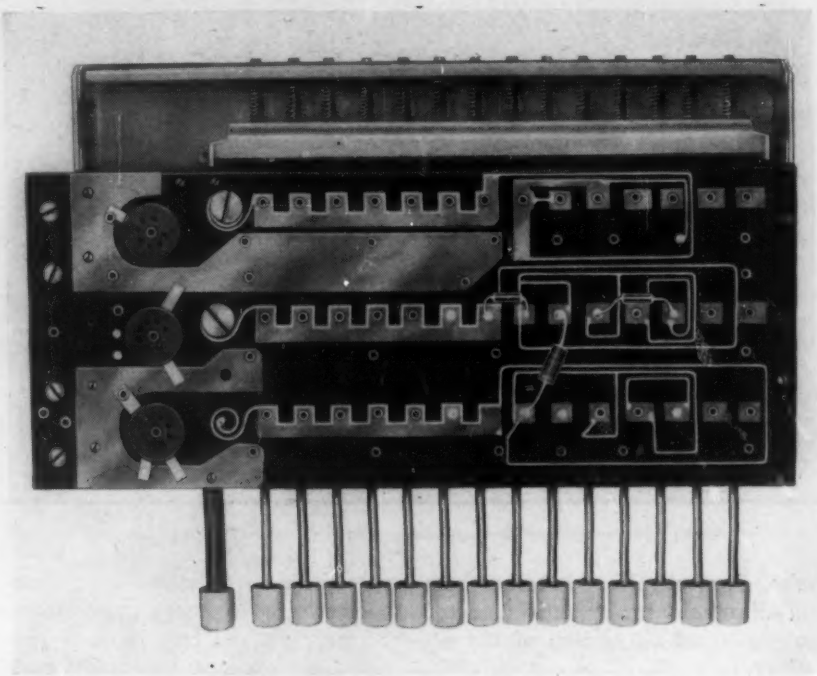
On the plus side of the ledger, rotary-switch advantages include low cost, sturdy construction, and noise-free operation. The spacing between the contacts is small, lending itself to high-frequency operation. Switches of this variety are compact and therefore keep the overall size of a unit to a minimum. But this is the very feature that sometimes causes trouble. Because of its compact construction, the average rotary switch is not too accessible in production. Also, the concentration of conventional inductances in a small enclosed area in which there are warm resistors and hot tubes contributes to the drift problem. Use of printed or stamped inductances as shown in the upper photograph on the preceding page eliminates most of this trouble.

Rotary Turret. Theoretically, the rotary turret represents excellent television head-end design. By rotating coils, lead lengths can be kept constant for all channels, providing a good LC ratio. But this system, too, has disadvantages. Contacts are difficult to design and, if satisfactory, are generally very expensive. Also, size easily gets out of bounds if all twelve channels are provided. Some manufacturers circumvent this by providing eight channels, leaving it to distributor or retailer to make a station selection satisfactory to the consumer.

Sliding Turret. The sliding turret is essentially a rotary turret that has been flattened out so that it can be moved sideways over or under a set of stationary contacts. Among turrets, it is probably a good type as contacts are not too difficult to design. However, it has still greater size and more complex mechanical structure.

Permeability Tuning. Permeability tuners have been used successfully for years in radio receivers, and there is no reason why they cannot be adapted for television if the designer is willing to take the disadvantages along with the advantages.

To begin with, in order to cover the entire television band, the tuning spectrum has to be divided into at least two bands, with some method of switchover provided. Such a system could be used in two different versions, the first as a continuous-tuning device and the second with a detent and individual channels. The first system has the advantage of smooth operation but it will also tune through all kinds of interferences. Placing a detent in the system eliminates this trouble but complicates the problem of resetting. Inasmuch as permeability tuning in most cases depends on very small inductance changes, the problem of bringing slugs back to exactly the same position for given



Franklin push-button-type tuner formed of stampings

channels is very difficult indeed.

Inductive Tuning. Inductive tuning has the advantage of smooth operation. On the other hand, it is mechanically complex and expensive. The idea ordinarily involves use of a rotating cylinder upon which wire is wound in grooves. A small contact wheel engages the first turn when the coil form rotates, and travels over its entire length as the cylinder is turned.

Variable Capacitance. The old reliable workhorse of radio, the variable capacitor, has not been forgotten. Although most designers have not employed such devices because of the wide frequency range that must be covered in a television head end, one has actually been developed. The unit referred to requires a high-low bandswitch.

Pushbutton. Two different pushbutton tuners have been developed. The first uses a conventional pushbutton switch and the three associated tubes are mounted on the main television receiver chassis rather than in the head-end unit. To overcome the normal high inductance of the contacts, a series capacitor is placed in the transmission line and a small variable capacitor at each pushbutton position to ground. The capacitors act as padders. For 12 channels, 36 trimmers are thus used.

The second pushbutton switch referred to comprises a framework designed to accommodate tubes and wiring. Space is provided near the converter tube for the first i-f coil or trap, while more space is available for broadcast or f-m components. Contacts are large and heavy and their inductance at the frequencies used is low. The moving contacts are welded to the pushrods and are self-aligning. Incorporated in this unit, and an important part of its design, are die-stamped circuits.[1]

Pushbutton Tuner Details

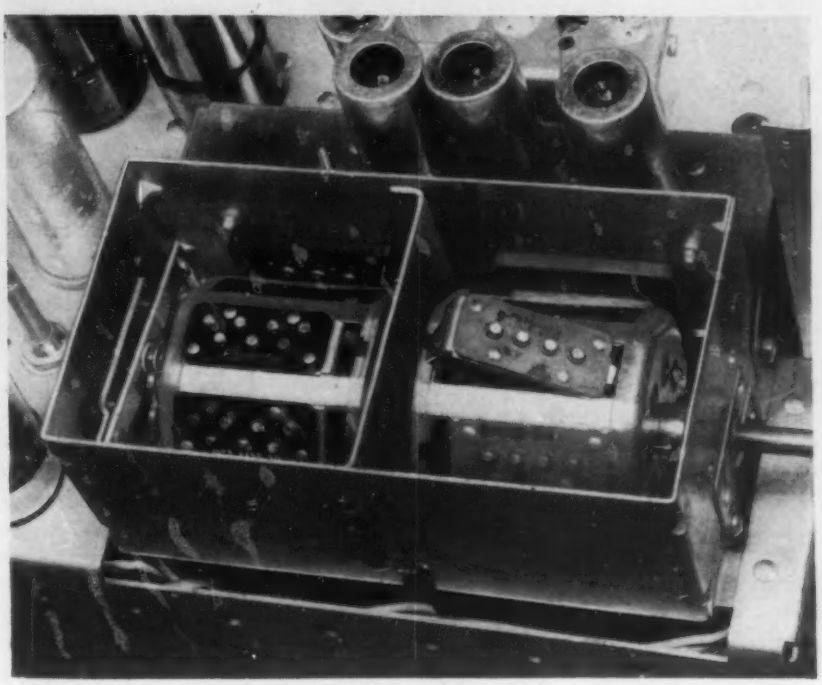
In the Franklin Airloop Corporation pushbutton tuner referred to above only four adjustments are necessary. Three coils have an inductive-tuning arrangement consisting of a 4/32 brass screw with a $\frac{3}{8}$ head. Moving the head of the screw closer to or farther away from the die-stamped coil provides necessary frequency adjustment. A similar device in the oscillator circuit tunes the low-frequency channels.

The oscillator has a vernier capacitance adjustable through the front of the tuner. In cases where automatic frequency control is used the vernier becomes an internal adjustment to compensate for different tube capacitances when and if the oscillator tube is replaced.

A 6BH6 tube is incorporated in the r-f stage. The antenna input is between grid and cathode terminals and is balanced and matched for a 300-ohm line. The grid of the tube may be used with automatic gain control. The plate is tuned and overcoupled to the grid of the converter, which is a 6AG5. The grid of the converter is tuned and the two circuits are coupled with fixed capacitors before channel 13 and at channel 7. Injection voltage at the grid averages 3 volts.

The oscillator is a conventional 6C4 with plate grounded with respect to r-f and a choke in the cathode circuit. The grid of the oscillator is tuned.

The heavy framework of the tuner readily dissipates heat, while the stamped inductances are comparatively far away from the heat sources. Oscillator drift is readily compensated for by means of temperature-coefficient capacitors when the tuner is used in different chassis and cabinets. Should a situation arise in which spurious signals are received in particular locations a trap for the offending signal, or an additional tuned circuit to bring up the wanted signal, or both, can be readily added. Threaded holes are provided on the rear of the switch for this purpose. However, no spurious responses have been found so far.



Philco rotary turret using replaceable coil assemblies

Future Trends

Present-day tuners serve their purpose well, considering the economics of the market, but already new and better front ends are on the drawing boards for 1949 and 1950. It will take time to complete design, field test and tool up.

The trend is toward more gain, greater stability and, particularly, greater freedom from interfering signals. Multiple stages of r-f are possibly in the offing. Certainly more tuned circuits are coming.

REFERENCE

(1) Stamped Wiring, ELECTRONICS, p 82, June 1947.

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High-Speed Revolution Counter

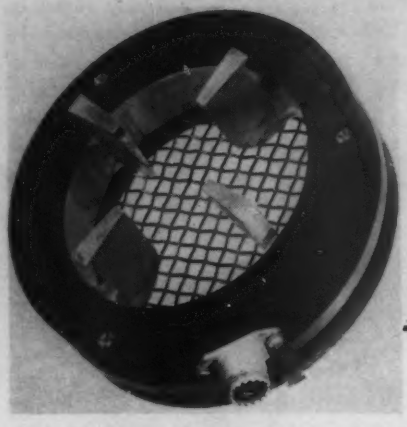


FIG. 1—Pickup unit, showing dural vanes

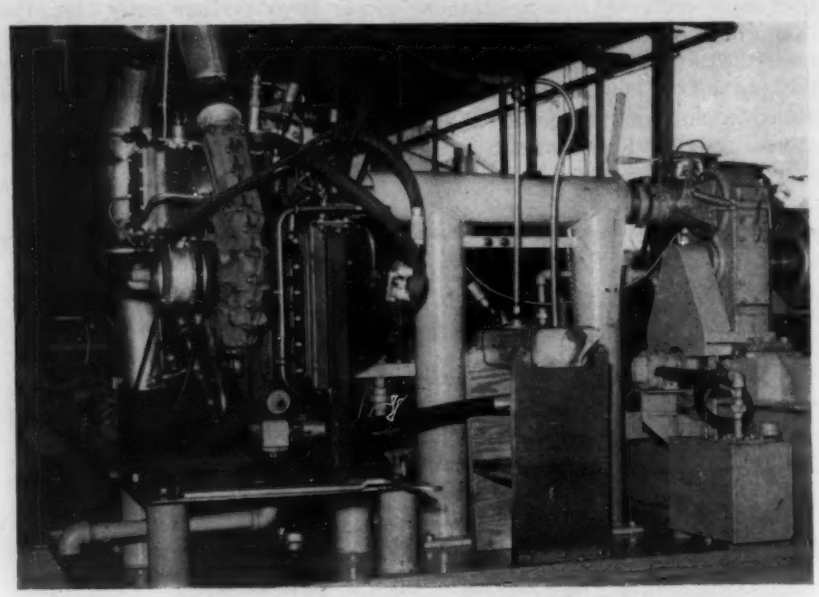
Supercharger impellers for DC-6 and DC-9 aircraft cabins are tested up to 30,000 rpm by means of a capacitance pickup, a transducer, and a frequency meter. No mechanical connection is made to the impeller shaft, and no load is added to the system

By ALVIN B. KAUFMAN
Douglas Aircraft Company
Los Angeles, California

THERE has long been a need for a revolution counter for high-speed machinery which does not attach to the rotating shaft or load it in any way. A device which fulfills these requirements and which is particularly suited for indicating rpm or rps of rotating fan, propeller or impeller blades is described.

The units illustrated are presently employed for determining the rpm of engine-driven cabin superchargers. The impeller of such superchargers operates at 30,000 rpm or more. Similar units can be adapted for use with turbines, or any rotary-blade machinery, without altering or adding anything to the machine.

Three items of equipment are required. These are: the pickup, a capacitance transducer, and an electronic frequency meter or tachometer. The pickup consists of one or more insulated vanes, located adjacent to the rotating shaft or attached blades so as to vary its capacitance to ground with rotation of the shaft. The capacitance-transducer supplies an alternating voltage whose frequency is proportional to shaft rpm. The alternating voltage is applied the electronic frequency meter or tachometer which employs a scale calibrated in terms of rpm revolutions per minute.



Test stand for an aircraft cabin supercharger

Pickup

As the pickup works on a capacitance principle, it is necessary to use a connecting cable whose capacitance is low and yet constant despite movement or vibration. A suitable cable is RG8/U coaxial.

The variation of pickup capacitance should be at least five percent of the total input capacitance, but operation on smaller percentages is possible under low vibration conditions. A one-vane pickup was originally used and proved satisfactory up to 10,000 rpm, but was later discarded in favor of a four-vane pickup pictured in Fig. 1. It should be noted that the number

Control panel for the revolution counter

of pickup elements does not change the output frequency, which is determined by the number of vanes or blades on the rotating shaft. However, under extremes of vibration or weaving of the rotating blades a high degree of hash may be produced. These stray variations in capacitance are corrected by the use of a multielement pickup which automatically balances them out. As one blade weaves closer to a vane its increase in capacitance is balanced by another blade, 180 degrees away, moving away from a vane or pickup element. With the four-element pickup, good waveform is delivered to the electronic frequency meter.

There are several other factors that must be considered in the design of the pickup. In theory it is nothing but an insulated metal plate. The size and shape is not critical, but is chosen so that the impeller blade is not under the plate for more than 50 percent of its travel before the next blade passes under the plate. This gives roughly a 1-to-1 low to high capacitance cycle, delivering through the transducer a substantial sine wave. The electronic frequency meters or tachometers require an on-to-off or vice-versa alternation of input voltage preferably 1 to 1 but not to exceed 4 to 1 for a highly accurate indication.

The spacing of the plate or pickup vane to the element depends upon input cable capacitance, spacing between impeller blades, and transducer sensitivity. Using a two-foot RG8/U cable with the pickup illustrated, spacings up to one-quarter inch have been employed. Spacing may best be determined by test, but in any case close tolerances are unnecessary. Airflow restriction may be limited to a low value by proper design of the pickup. This again hinges upon use of the pickup in different fields.

Transducer

The transducer unit changes variation in pickup capacitance into useful audio-frequency voltage suitable for application to the electronic frequency meter or tachometer. It consists of the familiar capacitance relay or radio-frequency oscillator, a detector and a one-tube amplifier, as shown schematically in Fig. 2.

The r-f oscillator is adjusted to oscillate feebly. The pickup is connected so that every time its capacitance increases it shunts the oscillator-feedback circuit more, and thus causes the oscillator to drop its r-f output voltage. The r-f carrier is rectified and the a-c component caused by variations in signal due to changing pickup-plate capacitance is amplified. Output must be over two volts, but not over two hundred, to operate the frequency meters or tachometers in use. As the output voltage is not critical and does not affect the rpm indication, the transducer requires no gain stabilization.

The oscillation frequency of the

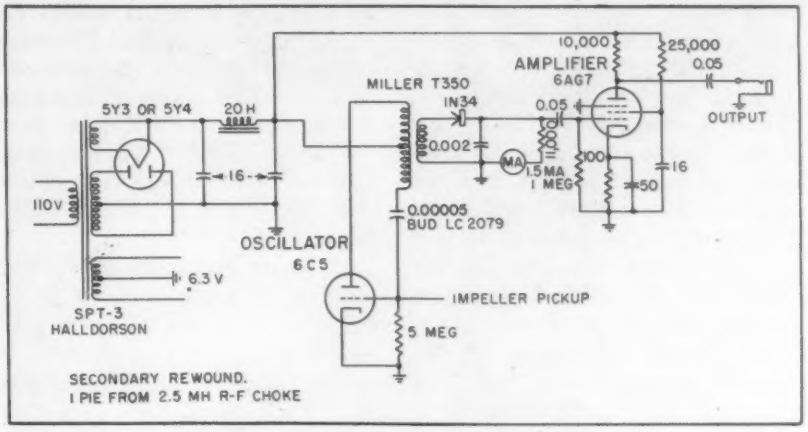


FIG. 2—The capacitance transducer. Plate series capacitor is variable

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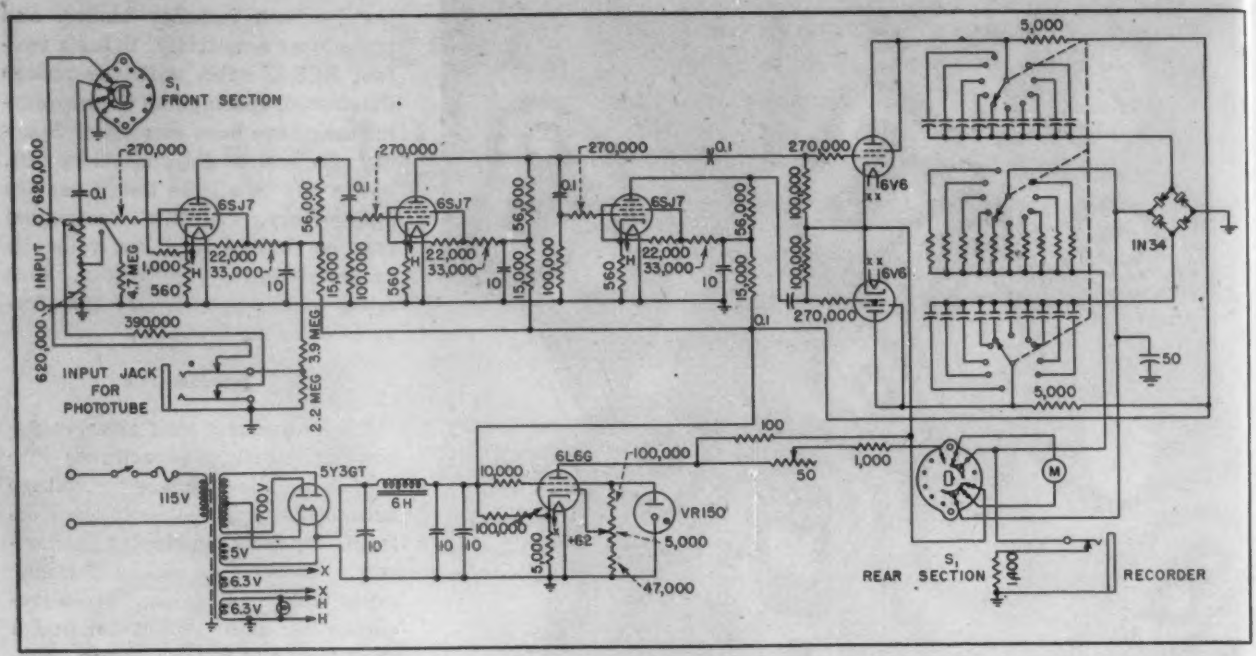

FIG. 3—Circuit of Hewlett-Packard frequency meter and tachometer used as a speed indicator for testing cabin superchargers

transducer is not critical and for this reason the oscillator coil is not tuned. Where the particular coil specified in the drawings is not available, the oscillator should preferably be set to operate between 500 and 2,000 kilocycles. This, in part, depends upon the capacitance change available in a particular application. Input capacitance as well as the size of the feedback variable capacitor determines optimum frequency.

The setting of the variable capacitor will depend upon three feedback functions: frequency of oscillation, feedback ratio in tank coil, and cable and pickup shunting capacitance. Optimum capacitor setting may best be determined experimentally for each individual application. The capacitor is adjusted to the point where the oscillator is not oscillating strongly. This is accomplished with the aid of the 1.5-ma meter, which indicates rectified r-f current from the detector. The output winding on the tank coil is wound so as to give a 1.0 to 1.5-ma indication on the meter when the oscillator is functioning correctly.

The output impedance of the original transducer was not considered critical, as the output voltage was high and a shielded cable was to be used. However, this developed into a critical point because of the high output frequency. A sixteen-blade impeller, rotating at 30,000 rpm, has an output frequency of 16 times 30,000 divided by 60. This gives an output frequency of 8,000 cycles. Therefore, in the first units is was necessary to use RG7/U cable (14 μμf per ft.) to connect the transducer to the frequency meter. The amplifier tube and circuit components were then changed to give lower output impedance.

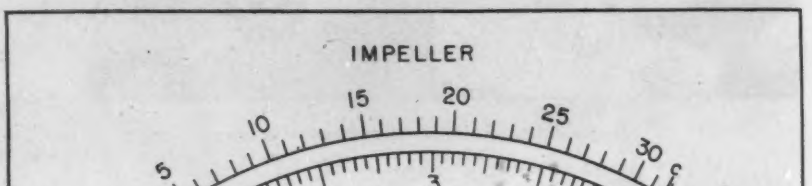

FIG. 4—Redrawn frequency-meter scale, giving rpm directly

It would be desirable, in new units, to use a plate-to-500-ohm-line transformer in the transducer and a 500-ohm line to grid transformer at the frequency meter or tachometer. Thus there would be no limitations on cable length between the two units.

The rpm may be read directly on the electronic tachometer diagrammed in Fig. 3. One cycle is produced per revolution at the pickup. Where many-bladed devices are used it is preferable to use an electronic frequency meter. In this case, rpm may be read by using the calculation rpm = freq. × 60 ÷ no. blades. This calculation may be reduced to chart form, but it is preferable to draw a new scale to be used with the instrument, as shown in Fig. 4.

Acknowledgment

The author wishes to thank Bruce Duncan of Douglas Aircraft for his cooperation in the mechanical designs and helpful criticism leading to the successful completion of this device.

Dielectric Heating of Thin Films

Development of electrode structures for applying high power to dielectric films is described. Limitations imposed by air gap for usually encountered applications are analyzed. It is also shown that average power should be close to instantaneous peak power

By THEODORE C. GAMS

Chief Engineer
Allied Laboratory Instrument, Inc.
New York, N. Y.

Solvent, used to flow film onto a cellulose backing, is preheated before being removed in an oven. Using the electronic preheater increased productivity of the plant 40 percent

ALTHOUGH DIELECTRIC HEATING has established itself as an industrial process, its application in some fields has been limited by difficulties in load matching; that is, the design of appropriate electrode structures for the efficient transfer of power to the work to be heated.

One field of application in which load matching has been particularly troublesome is the heating of thin films or sheets of either liquid or solid material. This field embraces a large group of industrial processes, as shown in Table I.

Difficulties of Heating Films

To appreciate the problems presented by loads consisting of thin films, consider Fig. 1A. A typical film, often less than ⅛-inch thick and several feet long and wide, constitutes the dielectric of a flat-plate capacitor. The dielectric constant of the load material is rarely less than four, and the power factor is generally not very high, perhaps five percent. If the film remains dry and solid during the heating process, so that it may touch the electrodes, the electrodes may be of the conventional parallel-plate type.

An examination of such a load shows: (1) high capacitance, due to close spacing and large area of the plates, (2) short air gap between plates, (3) necessity for flat, rigid, and parallel electrodes (to avoid air spaces which cause cold spots in the load), (4) loss of heat because the electrodes have high thermal capacity, (heating the plates by external means helps in eliminating this problem), (5) necessity for a high frequency to obtain rapid heating, because the short plate-to-plate spacing will not permit the use of high voltages, (6) difficulty of obtaining uniformity of field with h-f and long dimensions due to standing waves across the electrodes. Stubbing is helpful in reducing nonuniformity, but does not eliminate the problem. If the load is moving through the electrodes, standing waves in that one direction are unimportant (7) generation of sufficient power at h-f required by a short cycle may be difficult (8) transmission of power to, and establishment of voltage across such a low capacitance at the desired h-f is often impractical (resonating the load by parallel stub inductances is sometimes possible), and (9) circulating currents required are often prohibitively high, because these loads raise allowable minimum generator tank-circuit current.

Air Gap Lowers Load Voltage

The parallel-plate problem is even more severe in loads which may not be touched on one or both surfaces by the electrode plates. There are several reasons for such a restriction. The surfaces may be wet, as

TABLE I—Principal Applications

Drying Plastic Coatings
Waterproofing textiles
Manufacturing artificial leather
Glazing cloth and paper
Drying Liquid Films
Baking paint and lacquer
Drying printing inks
Heating adhesive films (such as bookbinding and adhesive tapes)
Setting flocked coatings
Heating Solid Films
Curing sheets of resin (such as guttapercha)
Heat-sealing laminates (such as glass to paper, paper to wood, paper to paper and cloth to paper)
Drying Impregnants
Sizing cloth and yarn
Setting impregnated paper and cloth

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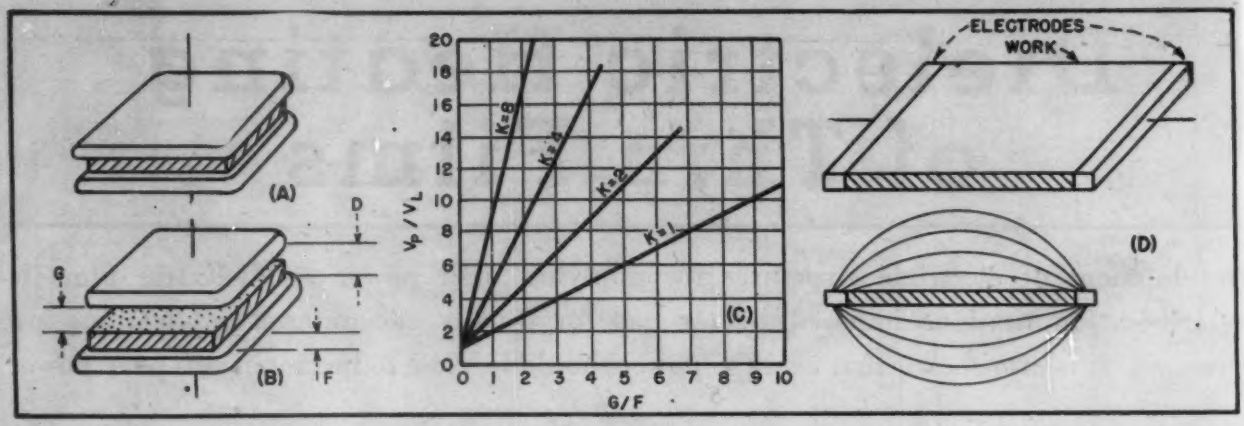

FIG. 1—Heating thin films by making them the dielectric of parallel plate capacitors (A) is difficult if there is an air gap (B) comparable to the thickness of the film, the ratio of applied voltage to load voltage is rising rapidly (C) with gap width. If it were not for excessive leakage (D) the electrodes could be placed at the edge of the film

in the case of adhesives and paints. The surfaces may give off water or other solvent vapors while heating which must escape freely. In the case of curing sheets of natural resins, the material is often too fragile to withstand pressure.

In the above examples, an air gap (Fig. 1B) must be maintained between load and one or both electrodes. This air gap creates further load-matching problems. In both Fig. 1A and 1B the minimum voltage V_B at which ionization will occur in the air space extending from the edge of one electrode plate to the edge of the opposite plate is $V_B = K_B D$ where D is the spacing between plates and K_B is the dielectric strength of air, which is nearly constant for well-rounded plates spaced fairly close together.

The load voltage V_L required to accomplish the desired heating (at any one frequency) is $V_L = (P/\omega C_L \cos\theta)^{1/2}$ where P is the average power required by heating cycle plus losses, ω is $2\pi \times$ frequency of operation, C_L is capacitance represented by the load itself, and cos θ is the power factor of the load.

In Fig. 1A, V_L is equal to the plate-to-plate voltage V_P because there is no airgap. In Fig. 1B it is V_P is somewhat higher than V_L, due to the series air-gap capacitor C_G of thickness G, the same area as C_L, but having a dielectric constant of only unity.

Neglecting the effect of the resistive component of the load R_L the plate-to-plate voltage must be at least $V_P = V_L (C_L/C_P)$ where $C_P = C_L C_G / (C_L + C_G)$, the equivalent capacitance of the load capacitor and air-gap capacitor in series.

Because air has a dielectric constant of unity, and the lowest dielectric constant commonly encountered for film materials is about four, it is apparent that, if G is made equal iof F (and it often must be ten or more times as large) the plate-to-plate capacitance C_P is no more than $C_L/5$.

The required plate-to-plate voltage V_P has thus been increased, by the presence of the air gap for $G = F$ to 5 V_L, or five times the plate-to-plate voltage required with no air gap. This illustrates the fundamental difficulty introduced by air gaps. In the above example, the minimum breakdown voltage with air gap is only twice the minimum without air-gap, because $F = G$.

Of course, when the dielectric constant of the load is nearly that of air, or when the spacing is very small compared to the film thickness, the effect of an air gap may be small. Figure 1C is a plot of V_P/V_L vs G/F for different values of K, the dielectric constant of the load.

The above analysis holds for any load in which the power factor is low enough so that the resistive component of the load may be neglected. The difficulty increases if the power factor is high, because the ratio V_P/V_L becomes even larger.

Some advantage is obtained because the air gap reduces the heat losses to the electrode plates, and thus reduces the required load voltage. This advantage does not, in general, compensate for the rise in V_P, except for very small air gaps.

The basic limitation inherent in the parallel-plate method arises from attempting to heat the material through its thin dimension. Most of the difficulties outlined above would disappear if it were possible to cause large r-f currents to flow through one of the long dimensions of the film.

There are two methods of achieving longitudinal currents: (1) by direct connection to the edges of the film, and (2) by stray-field configurations. Figure 1D shows that the aspect ratio of the capacitor formed by the direct-connection method is extremely high, thus causing very low efficiency; electrical and thermal radiation losses and fringing are high, and the apparent power factor of the load is many times lower than the actual power factor of the load material. The only applications in which a high aspect ratio is acceptable are those in which both power factor and dielectric constant of the load material are very high, as in the case of thin films of water-borne adhesives, although even then aspect ratios greater than 100 are to be avoided.

Stray-Field Heating

The stray-field method of causing longitudinal currents to flow is generally superior to the parallel-plate method. A number of practical configurations are shown in Fig. 2. The field intensity due to any of these electrodes is nonuniform across the length of the film, which requires that, if the film does not normally move continuously past or through the electrodes, it (or the electrode structure) must be moved

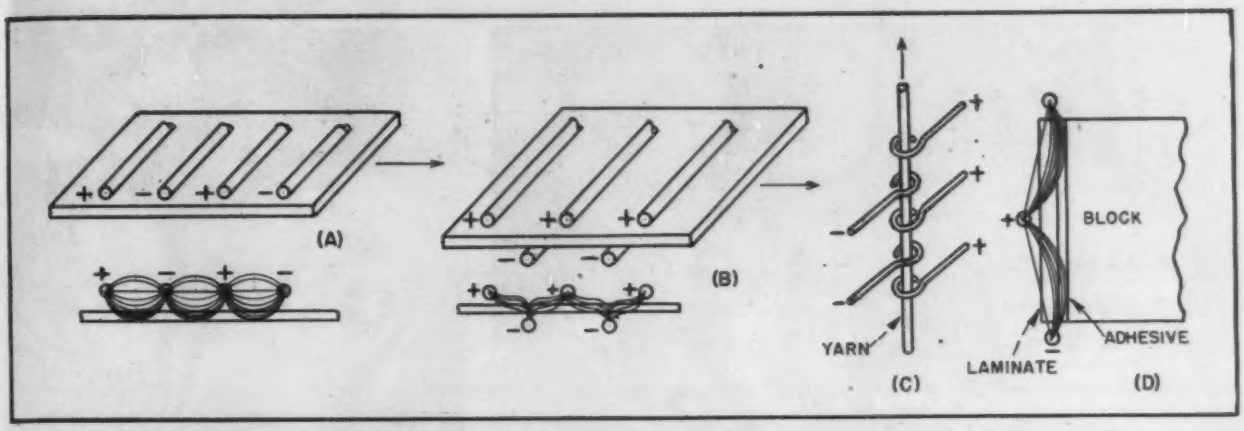

FIG. 2—Arranging electrodes of opposite polarity adjacent to each other along the film (A) or on opposite sides of it (B) minimizes the effect of air gap. The technique can be applied in various ways (C) and (D) depending on requirements

by a suitable oscillating or continuous conveyor system. However, at least 80 percent of the thin-film loads encountered in h-f heating are incorporated in continuous-production processes which not only require very little mechanical revision for the use of the electrodes of Fig. 2 but also provide the motive power for the film.

Electrodes of the type illustrated have none of the disadvantages outlined previously. Furthermore: (1) the capacitance represented by the electrodes (with the load in place) is relatively small, (2) the air-gap between electrodes is relatively large, and the electrodes themselves are generally cylindrical or of a similar shape which discourages arcing, (3) exact alignment of the electrodes is unnecessary because the relative motion between the film and the electrodes tends to cancel misalignment errors, (4) little or no heat loss occurs because the electrodes may be designed with small mass, and, even when in direct contact with the film, present a very small area of contact, with a consequently small conduction loss, (5) the field intensities required to perform a given job of heating are generally lower than those required by parallel-plate electrodes, (6) by means of relatively simple coupling networks it is possible to feed long sections of these electrodes with h-f power without difficulty due to standing waves, (7) because voltage requirements are not as restrictive, and because arcs are discouraged by this type of electrode, most work can be done below 30 mc, which simplifies the power generation problem, (8) the transmission of power to and the establishment of voltage across these electrodes may be accomplished by ordinary methods, and (9) the circulating currents required by loads of this type are not excessive, and conventional generators will readily handle them.

The disadvantages of maintaining an air gap have not been eliminated by selecting this different method of introducing r-f currents into the load. But selecting this type of electrode permits a wider margin of safety between required plate-to-plate voltage and the minimum breakdown voltage of the structure.

All of the electrodes illustrated in Fig. 2 are practical. Selection of the proper one for a given problem is dictated by such factors as: (1) whether or not the electrodes may touch the load, (2) the type of mechanical structure permitted by the process to which h-f heating is being added, and (3) the power factor, dielectric strength, and mechanical characteristics of the film to be heated.

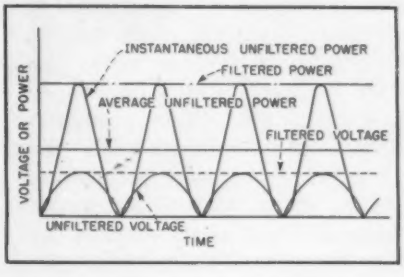

FIG. 3—Arcing at the applicator electrodes limits the peak voltage that can be applied. By filtering the power supply the effective rate of heating can be about doubled

Because of the shape of the electrodes, they tend to radiate considerably, and must be shielded. Tunnel shields which fit around the electrodes snugly and extend some distance beyond them are quite effective. Radiation losses under shielded conditions are negligible. It is important that all surfaces of the electrode structure, particularly the ends of the electrode bars, be well rounded and polished. It is best to use large diameter rods with half-sphered ends.

Design engineers will find that there is an optimum ratio of spacing of the electrodes to their diameters for any given configuration and load. This ratio is often affected by the number of electrode pairs used in an array. Arrangements which permit the electrodes to acquire a coating of any foreign substance, such as adhesive drippings or bits of plastic film should be avoided. Such particles encourage arcs.

Filtered Power Supply

In dielectric heating applications where the power to the load is limited by the arcing voltage dictated by the electrode shape, the maximum average power transmitable to the load may be increased up to 100 percent by filtering the plate supply to the oscillator tubes, if it is not already a pure d-c. That this is so may be seen from Fig. 3.

The author is indebted to John F. Dreyer, Jr., consulting engineer, and Ernst Massey, who devised the arrangement of Fig. 2B, for their cooperation and collaboration in various phases of this development.

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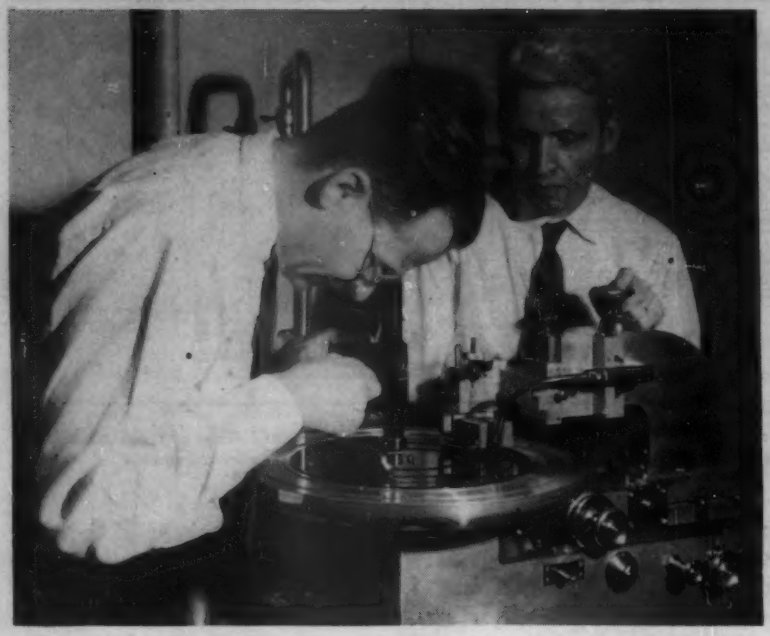

Peter C. Goldmark of CBS microscopically examines a new long-playing disk while Rene' Snepvangers looks on

William S. Bachman (standing) discusses one phase of the manufacturing process

Transcription Recordings

New 33-1/3 rpm recording system, cuts up to 300 grooves per inch, achieves low noise with Vinylite and pre-emphasis, Result: a six-record album on a single 12-inch pressing

A NEW APPROACH to satisfy the public demand for long-playing recordings has been jointly announced by Columbia Records Inc., a CBS subsidiary, and the Philco Corporation.

The new recording system, developed by Peter C. Goldmark, René Snepvangers, and William S. Bachman of Columbia, achieves a six-fold increase in recording time per disk by combining 33⅓ rpm transcription-standard turntable speed with an extremely fine pitch of approximately 260 grooves per inch. The decrease in turntable speed from the home standard of 78 rpm introduces a time factor of 2.35, while the larger number of grooves, compared with 85 to 100 per inch typical of conventional home records, provides an additional factor of about 2.6 times. The net result is that as much as 50 minutes of recording time can be accommodated on the two sides of a 12-inch disk, compared with 8 minutes on the older type. The records are known as LP, for long playing.

This is not the first time that 33⅓ rpm disks have been produced for the home market, but it is the first in which a system has been primarily engineered for this market. Earlier attempts failed because the groove pitch could not be made fine enough to secure a substantial increase in recording time, and the noise and distortion were high. Also, home-type turntables of earlier days tended to have excessive wow when operated at 33⅓ rpm. These problems were attacked by Peter Goldmark, well known for color-television developments, and his associates. The Philco Corporation undertook the design of a record reproducer which would meet the stiff requirements of low-speed service and still be marketable at a reasonable domestic consumer price.

Philco has also designed a two-speed turntable with a separate arm for the LP records.

Keys to the success of the new system are the use of Vinylite plastic for the pressings, the development of a new, efficient, light-weight reproducing arm and cartridge and mechanical refinements in the turntable driving mechanism. A pre-emphasis characteristic designed especially for the system, resembling closely the NAB standard transcription curve, was introduced to achieve high signal-to-noise performance. Also, many unconventional techniques have been adopted, including a degree of over-cutting which would not be acceptable in making conventional recordings.

Design Details

The grooves are about 0.003 inch in width, roughly one third the size

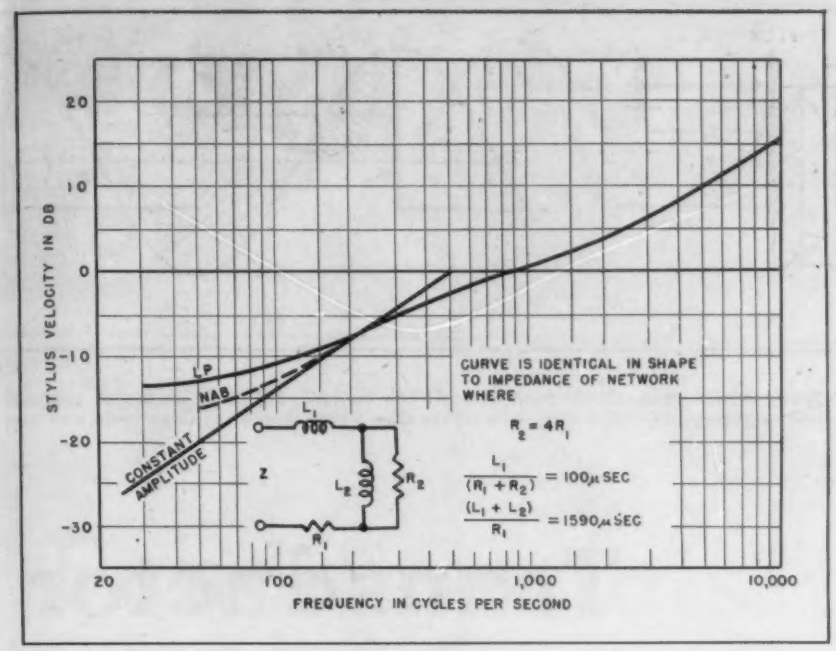

FIG. 1—Characteristics of new long-playing (LP) record, NAB transcription standard, and one having constant amplitude

for the Home

of the standard record groove. Consequently, it is not possible to record at as high a level, by about 9 db as if the cut were held proportional to the groove width. Actually, the level recorded is about 4 db below the usual reference. The 4-db loss in level would not be acceptable if the record material were of the shelac type, but the low-noise properties of Vinylite together with the lightweight pickup permit a highly acceptable noise level to be achieved while maintaining a dynamic range in the order of 45 db. The consequent smaller excursion of the reproducing needle reduces the cartridge output by 4 db, but an efficient crystal has been developed which provides 0.7-volt output at reference level. Accordingly, no high-gain preamplifier is needed in the reproducing system.

The groove shape has an included angle of about 90 deg, and the tip radius is under 0.0002 inch. Accordingly, it is not possible to reproduce the new pressings with a standard 0.003-inch stylus. The cartridge perfected by Philco engineers, uses a balanced Rochelle-salt crystal and a groove pressure of only 6 grams (one-fifth ounce). It employs a semipermanent metal stylus lapped to a tip of 0.001 inch radius. The light pressure and small radius permits the stylus to follow the fine groove with tracking distortion lower than conventional practice. The stylus may be replaced without replacing the cartridge, if desired. To keep distortion at a low level, the diameter of the innermost groove has a minimum value of 5¾ inches, which is almost two inches greater than that of conventional commercial domestic 78-rpm pressings.

The practice of pre-emphasis has been standardized in the new records, using the characteristic shown in Fig. 1. Above 200 cps, the curve is identical with the standard NAB transcription characteristic, reaching 16 db pre-emphasis at 10,000 cps, relative to the 900-cps value. Below 200 cps the characteristic is higher than the NAB, being about 7 db above constant amplitude at 50 cps. The similarity of LP and NAB curves makes it possible to use the LP recordings on standard broadcasting transcription tables with no change in equalizing, although simple RC circuits suffice for equalizing in any event.

Turntable Requirements

The wow problem assumes a serious aspect at 33⅓ rpm, since the speed ratio (1 in 2.35 relative to 78 rpm) requires that variations in turntable speed be reduced by the same amount. The turntables thus far used are of the rim-driven type. Care has been taken in centering the inner edge of the table, and in balancing the motor. Use of a high-grade rubber rim on the idler wheel is mandatory. Moreover, the edge of the rubber rim must be mechanically ground to assure near perfect circularity. In the Philco turntable, the idler wheel is withdrawn from the motor shaft when the table is not turning, to prevent developing a flat in the rubber. The design of the table is such that no appreciable wow was discernible.

Releases and Results

The early releases of the new records consist of rerecordings from existing masters in the Columbia files. Fortunately, in recent years these masters have been made on lacquer, rather than wax, so they may be dubbed without damage directly to the 33⅓ master. More than usual care is required, however, to exclude dust and other foreign matter at every stage in the production of master, mother, and pressings, and the difficulty of securing freedom from blemishes for a 25 minute period (one side) is considerably greater than for 4 minutes. Before release, pressings are checked for technical excellence by engineers on the Columbia staff, a revolutionary procedure in the recording business.

The results, as judged by critical listeners, both technical and nontechnical, are excellent. In frequency range, dynamic range and distortion, the LP records outdistance shellac pressings and, with the possible exception of noise surpass 78-rpm Vinylite pressings.—D.G.F.

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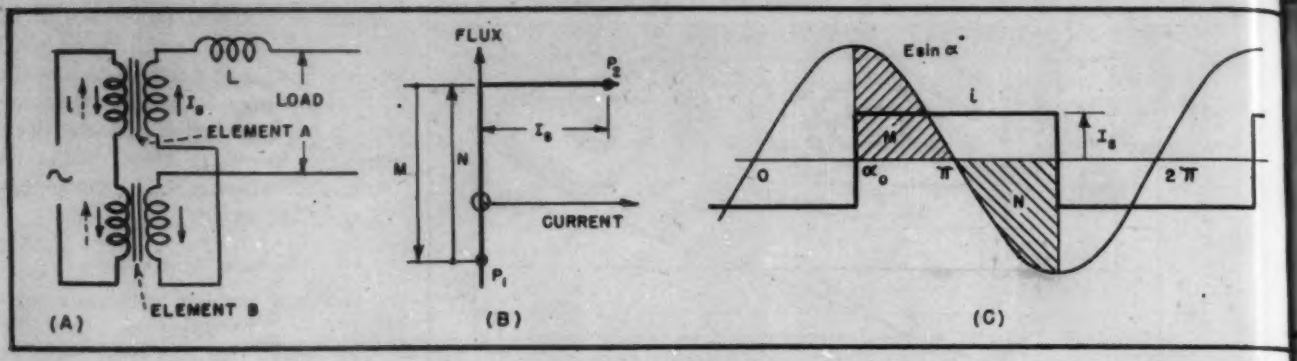


FIG. 2—Simple transductor connection (A) can be analyzed using portion of idealized magnetization curve (B). Voltage-time curves show action during operating cycle with zero

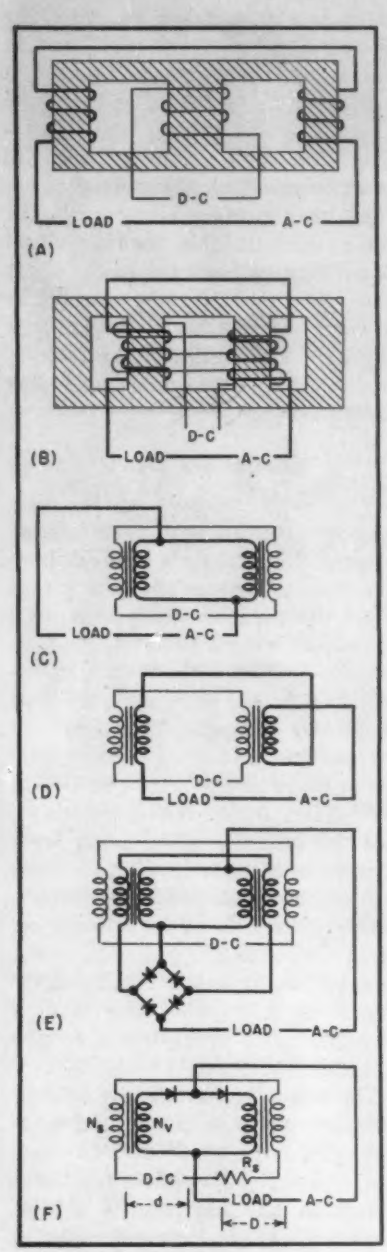


FIG. 1—Windings can be on one core (A) and (B), or on separate cores (C) to (F)

Transductor

By SVEN-ERIC HEDSTROEM and LENNART F. BORG

Regulator Dept.
ASEA Vasteras
Sweden

Rectifier Dept.
ASEA Ludvika
Sweden

IF A LOW alternating voltage is applied to a coil wound on an iron core the coil acts as an inductance the value of which is determined by the permeability of iron.

If the operating position on the curve is displaced by applying direct current through a separate winding the incremental permeability then acting diminishes as the position approaches saturation. In this way it is possible to vary the inductance between wide limits.

Because comparatively small direct control current is required the losses incurred in regulating large power are small. Thus a large power amplification is obtained.

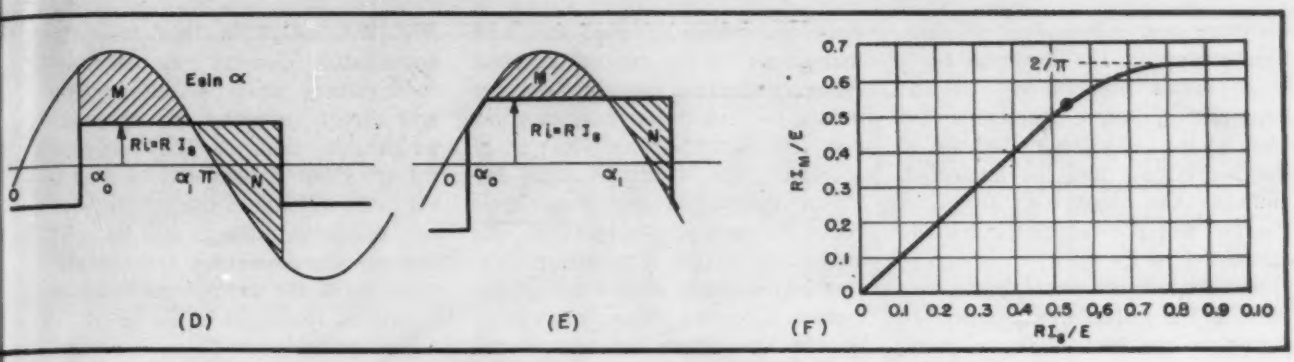
In practice, efficient operation of a direct-current presaturated reactor necessitates employing wide variations of flux. Under such conditions it is inappropriate to base investigations on incremental permeability. Work carried out by Boyajian,[1] Kramer[2] and Lamm[3] has paved the way for an appreciation of the mode of operation and that indicates the basis for calculation and design. On this basis Lamm[4] and others have investigated different couplings and dynamic properties. Instead of studying variations of permeability, variations of flux are investigated and an idealized magnetizing curve having constant slope and abrupt complete saturation is used.

To obtain an indication of flux variations, consider Eq. 1 where ϕ represents the flux in a coil, N the number of turns, and e_1 the induced voltage. From Eq. 1 we can write Eq. 2

$$e_1 = N d\phi/dt \quad (1)$$

$$\int e_1 dt = \phi_2 - \phi_1 \quad (2)$$

which shows that a variation in the flux corresponds to an area (voltage times time) on the voltage-time oscillogram. Using this principle, properties and operation of the d-c presaturated reactor can be analyzed. In this way the mode of operation is found to be different from what is generally termed a reactor, justifying another name.



resistance in a-c circuit (C), with moderate load resistance (D) and with high load resistance (E). In the latter case the control range reaches a limit as shown by the graph (F)

Fundamentals

Magnetic amplifiers are analyzed on the basis of voltage oscillograms, which facilitates interpreting laboratory measurements. Results of the analysis show the effect of load impedance on mode of operation and of supply frequency and inductance on speed of response

These controlled reactors are therefore called transductors.

To avoid the voltage that would be induced in the d-c control winding from the a-c power winding if the two windings were arranged on a single core, a symmetrical arrangement has to be used. Three or four-legged cores could be used. However, the three legged core shown in Fig. 1A has the drawback that its leakage flux impairs the transductor properties. On the other hand the four legged core of Fig. 1B is expensive to manufacture. A simpler arrangement is shown in Fig. 1C in which two separate cores are used. The induced voltages in the d-c windings of the connection shown in Fig. 1D do not counteract each other, but the connection has other advantages and interesting properties. Naturally the windings may be arranged in many ways. Especially, the need for d-c excitation can be minimized if the alternating current is rectified and used to excite the transductor by additional windings as shown in Fig. 1E. This is called a self-excited arrangement. Oscillograms of currents in the a-c and self-excitation windings of Fig. 1E show that the resultant ampere turns every moment are the same as would be obtained by means of only one winding connected in series with a rectifying element. The arrangement thus deduced is shown in Fig. 1F and is called simplified self excitation. By using this connection, winding space is saved in the same way as in an autotransformer. Simplified self-excitation connections can be varied in numerous ways.[5] Single and multiple phase connections are used; the three-phase connections have been treated by Lamm.[4,6]

Mode of Operation

The mode of operation of the connection shown in Fig. 2A can be explained simply if certain assumptions are made: (1) the magnitude of the control circuit current I_g is

UTILITY OF TRANSDUCTORS

Transductors can be self-excited and made to operate as trigger circuits. Thus they can be employed as relays; their opening and closing values are set by applying counter-biasing ampere turns.

Like the electronic amplifier, the transductor can also be made to oscillate. Low-frequency oscillations can be obtained readily.

Electronic amplifiers possess speed that is difficult to obtain with transductors. On the other hand, transductors provide stable low-frequency a-c and d-c amplification with a minimum of equipment. Where loads inherently have long time constants, as in many regulators, inertia of the transductor is negligible.

Transductors require current, whereas electron tubes require voltage for control. A combination of the two may provide excellent solutions of difficult problems. For instance, the transductor may supply voltage for controlling tubes, or tubes may supply current for controlling transductors effectively despite the induced voltages in control windings—

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constant and independent of time, represented in the diagram by a large series inductance, (2) the magnetizing curve possesses the ideal shape, (3) the resistance of the a-c circuit may be neglected, and (4) the number of turns on the a-c and d-c windings are the same.

The control current I_s gives element A the initial flux position P_2 shown on Fig. 2B and gives element B a corresponding position on the negative side. Fig. 2C shows the time variations of the characteristic magnitudes. The impressed alternating voltage $E\sin\alpha$ must be fully balanced in the circuit by variations in the flux in the two transductor elements. However, a change in flux is only possible when the number of ampere turns of one or both elements is zero, which means that an alternating current of the same magnitude but directed against the control current must pass continuously. Owing to the counter connection of the control windings on the two elements, this is not possible unless the alternating current commutates between positive and negative values in zero time, the values being of the same magnitude as the control current. No other current combinations are possible. Thus this transductor has a typical current-transformer characteristic, the linear relations between alternating and direct currents being independent of the magnitude of the alternating voltage. The phase of the a-c is determined by the requirement that the voltage across the transductor element cannot include any d-c component. In reference to Fig. 2C this means that the voltage-time areas M and N must be equal, making the control angle α_0 equal to 90 degrees.

It must further be observed that an alternating voltage at twice the supply frequency appears across the d-c terminals. The reactor L prevents this voltage from passing a superimposed current that would altogether change the mode of operation of the transductor.

When there is resistance R as load in the a-c circuit of the transductor, it might be expected that the current-transformer characteristic would be impaired. However, this is not the case, as shown in Fig. 2D. Also in this case the transductor element can only absorb voltage when the alternating and direct currents are of equal magnitude, and, as the resistive voltage drop is assumed to be insufficient to balance the supply voltage, the latter voltage will be split between the resistance and the element (area M) in the time interval α_0 to α_1, as indicated in the figure.

The lowest point P_1 on the magnetizing curve is reached at α_1 and a change in the current still cannot take place because, for it to do so, the magnetic state of the element from P_1 up to the saturation point would have to change by an amount requiring a voltage-time area just as large as that previously required to bring it down from the saturation point to P_1. Thus commutation will take place first when the area M becomes equal to N. When α_0 at an increased resistance drop reaches such a low value that RI_s becomes equal to $E\sin\alpha_0$ i deviates from the rectangular shape as shown in Fig. 2E and Ri coincides for a time with the sine wave. The current-transformer characteristics are thereby jeopardized and,

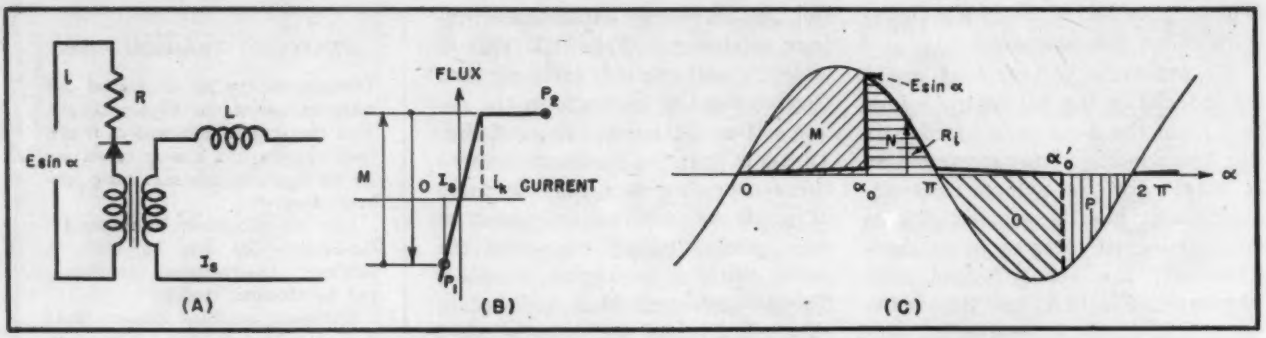


FIG. 3—Operation of a single element of a transductor with an ideal core

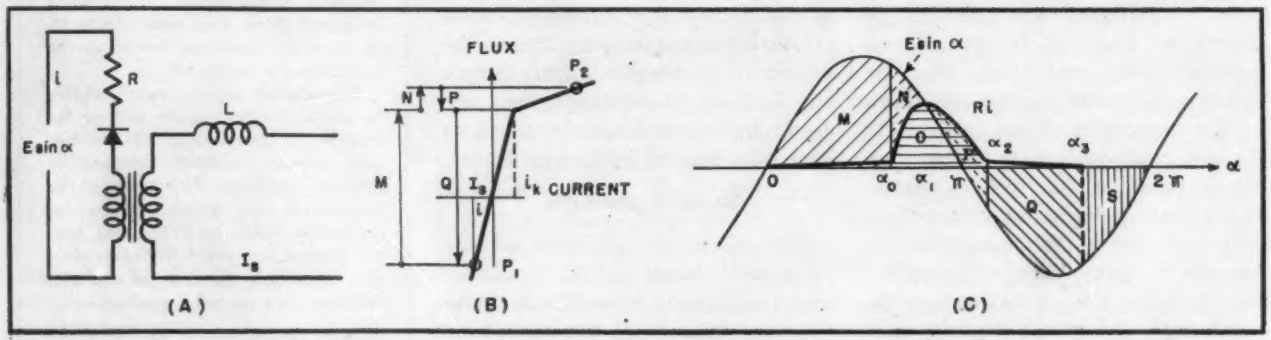
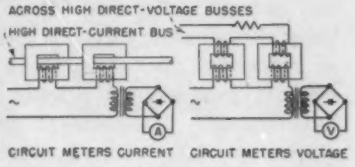


FIG. 4—Analysis similar to that of Fig. 3 but for imperfect core material

TRANSDUCTOR APPLICATIONS

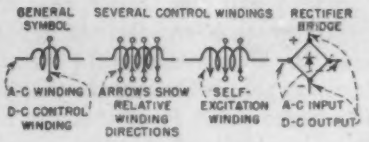
Transductors, like transformers are basic components that can be applied in numerous ways.

One type transductor possesses characteristics of a current transformer. It can be used to measure heavy direct currents or high direct voltages as shown in the accompanying illustration. Measuring

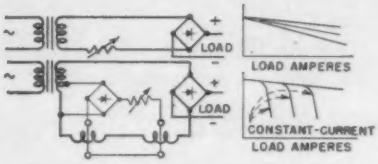


transductors can be built from ordinary transformer laminations and have an accuracy sufficient for service supervision (± 2 percent). By employing special laminations, higher accuracy can be obtained. In addition to the feature of complete isolation between the main circuit and the metering circuit, the measuring transductor has the advantages that the quantity operating the indicating instrument is a-c and therefore can be transformed to any desired value; measurement of summation and differential quantities can be made simply because the quantity to be measured appears as ampere turns, current is measured directly and not translated into voltage as in using a shunt (particularly important with remote measurements), and the power consumption is exceedingly low.

Voltage and current regulation is the most important application of transductors. For simplicity in drawing diagrams of circuits using transductors, rectifier bridges and the several windings of the transductor elements are shown in abbreviated form.

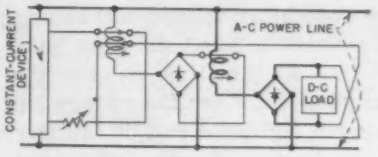


A metallic rectifier can be controlled by a simple series resistance giving the characteristics shown below, or a series transductor can be used. In the latter case power required for regulation is small and the output current is more



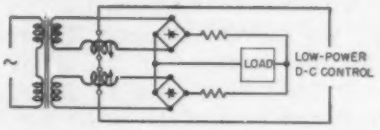
perfectly determined by transductor control current. Until limited by voltage, the current is independent of load resistance. Such circuits are extensively used in battery chargers for trucks and other cases where constant current is required. (For clarity the control portion of the circuit is drawn in lighter lines than the power portions.)

In charging batteries where the voltage must be kept constant, as in broadcast stations and telephone exchanges, a slightly more complex circuit is used. A self-excited transductor provides the regulation. This transductor is, in turn, controlled by a smaller unit the output voltage of which is determined by the total number of ampere turns of its excitation windings. A constant current supplied to one control winding in the same direction as the self excitation sets the regulated value. Another control winding fed



in opposition to the first carries the sensing current that is proportional to the load voltage. Because two transductors are used, the regulation is high. A rectifier of this type which can operate on both constant current and constant voltage is called an avostat. Avostat-regulated rectifiers can be built for all outputs for which metallic rectifiers can be used.

When very little power is available from a quantity to be measured, the high amplification of self-excited transductors can be used. The accompanying circuit shows a push-pull connection giving an output voltage the polarity and magnitude of which are determined by the control



current. Power amplifications as high as a hundred million may be obtained from similar connections. If gain is sacrificed for stability, such transductor circuits are suitable for amplifying currents from photocells and thermocouples—

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as shown in Fig. 2F, the relation between the currents follows a straight line only up to a certain point, whereafter it is deflected and asymptotically approaches a limiting value corresponding to the full alternating voltage being balanced by the resistance drop.

Transductor as Amplifier

For a transductor (Fig. 2A) with a resistive load in series with the a-c winding, amplification takes place because the a-c winding requires an input corresponding to only half the copper losses, whereas the load may rise to a value corresponding to the entire transformer output of the transductor. The method, described previously, of decreasing the need for d-c ampere turns by rectifying the a-c and feeding it back by means of a separate winding, or by inserting rectifying elements in series with the a-c windings, is analogous to the feedback used in electronic amplifiers whereby amplification is increased at the expense of linearity. The connection providing simplified self excitation (Fig. 1F) has advantages over that of Fig. 1E and is also easier to analyze. Therefore this connection will be treated in detail.

A transductor element and a rectifying element connected in series between two current-dividing points constitutes a common feature of all simplified self-excitation couplings. The connection, the assumed shape of the magnetizing curve and the mode of operation as represented by the oscillogram are shown in Fig. 3. A certain d-c bias

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is set by means of the control current I_s giving an initial position P_1, which represents the lowest possible value of flux because the alternating current will be prevented by the rectifier from passing through the transductor in such a direction as to force the flux still lower. In relation to the rectifier, the alternating voltage will be negative immediately before the point $\alpha = 0$. At that time no current i can pass, but after the voltage has changed sign at $\alpha = 0$ it can pass in the forward direction of the rectifier, producing not only a voltage drop in load R but also a change in flux in the transductor element.

It is now of great importance to assume that the voltage drop in R is small as long as $i < I_s + i_x$ and consequently may be neglected. The entire voltage-time area between the zero axis and the sine wave can therefore produce change in the flux as long as the magnetizing curve permits. The knee of the curve is reached at α_0 and further area beyond that of M of the same polarity cannot be absorbed by the transductor element. Instead, the entire voltage is transferred to the load, the current through R momentarily assuming a value at which the voltage balance; $Ri = E\sin\alpha_0$ and area N is swept out. When the voltage changes sign at $\alpha = \pi$ and the diminishing current passes the knee at the same time, the element can again absorb voltage (area O). At α_0' the current becomes zero and the remaining voltage-time area P acts across the rectifier until α becomes equal to 2π, whereafter the cycle is repeated. Because the voltage across the transductor element cannot contain a d-c component the areas M and O are equal and consequently areas N and P are equal.

Effect of Magnetizing Curve

Even if magnetizing curves of modern magnetic materials can be made to approach more nearly that of Fig. 3B' it is of practical value to be able to predict the properties of a transductor whose magnetizing curve departs from the ideal. How this is done, in comparison to the technique described in connection with Fig. 3, is shown in Fig. 4.

At α_0 the current cannot assume a value that impresses the whole voltage across the load because a change in the flux continues to take place within the saturation range. Thus the voltage is divided between the load and the transductor element (areas N and O). At α_1 however, the voltage across the element becomes zero, which means that the maximum point P_2 of the flux has been reached and that the current has reached its maximum value. Because the negative area P depends upon the current from P_2 falling off, the current will thereafter be maintained at a value exceeding that required by the alternating voltage. The relations between the areas (and as shown in Fig. 4B) are $M = Q$ and $N = P$, so that $O = S$.

Within the range α_0 to α_2 the current may be expressed as

$$i = (E/R)\,[\cos\phi \sin(\alpha - \phi) - \sin(\alpha_0 - \phi)\exp - \cot\phi\ (\alpha - \alpha_0)] \quad (3)$$

where $\phi = \text{arc tan} X/R$, X being the reactance, which is represented at the prevailing frequency by the slope of the magnetizing curve within the saturation range.

Multielement Transductors

The transductor connection just described, containing only one element, operates satisfactorily but in practice units comprising several elements are usually employed. There are two reasons for using at least two units: d-c excitation of the transformer feeding the transductor is avoided, and smoothing of the control current can be omitted because the voltages induced in the elements counteract each other in pairs.

The mode of operation and method of designing transductors comprising several elements can be predicted in the same manner as described above for one element. To show how this is done consider the connection of Fig. 5A, which is a widely used circuit in which the load is taken out as smoothed d-c. The magnetizing curve and oscillogram are also shown in the figure. The rectified current I_L is assumed to be smoothed to the extent that it is entirely relieved of pulsations. Within certain intervals the a-c will then be lower than the d-c and can pass through the rectifier without having to flow through the load. This mode of operation is termed current-peak rectification and is analogous to voltage-peak rectification by means of a rectifying element and a capacitor.

If the resistance of the transductor elements is assumed to be zero, the rectifying elements will never be subjected to reverse voltage. Consequently a change in flux in one of the magnetic elements produces an equal but opposite change in the other one; the rectifiers determining the direction of the current. Figures 5B and 5C show the behavior of the A element. A magnetic displacement in this element produces an equally large but opposite displacement in the other one. After α has become zero the entire alternating voltage is impressed across the A element. A very small excitation current i_A passes through the rectifier that is carrying load current without causing any voltage drop. The knee of the magnetizing curve is reached at α_0 and i_A rises more rapidly thereafter but still under the control of the magnetizing curve and the voltage areas M, N and O. At α_3 the current i_A becomes equal to I_L and flows in branches 1A and 2A of the rectifier and to the load. The reactor then prevents any further increase in i_A for a certain interval. Because no change in flux in the transductor can take place, the entire alternating voltage appears as a constant voltage D across the load and a voltage across the reactor corresponding to area P. Even after α_4 when $E\sin\alpha$ becomes smaller than D, i_A retains its value because there is no voltage available that might produce a change in flux tending to lower the current. After $\alpha = \pi$ such a voltage becomes available as indicated by area S and i_A decreases. From α_4, D is maintained by the reactor voltage (area Q) which has changed sign due to the tendency of the current to decrease. At α_5' current i_A regains the value corresponding to the lowest point on the magnetizing curve and the A element becomes inactive for the remaining half of the cycle. Because the connection is symmetrical, current in the B element begins to rise to rise at α_0' but does not affect the behavior of the A element.

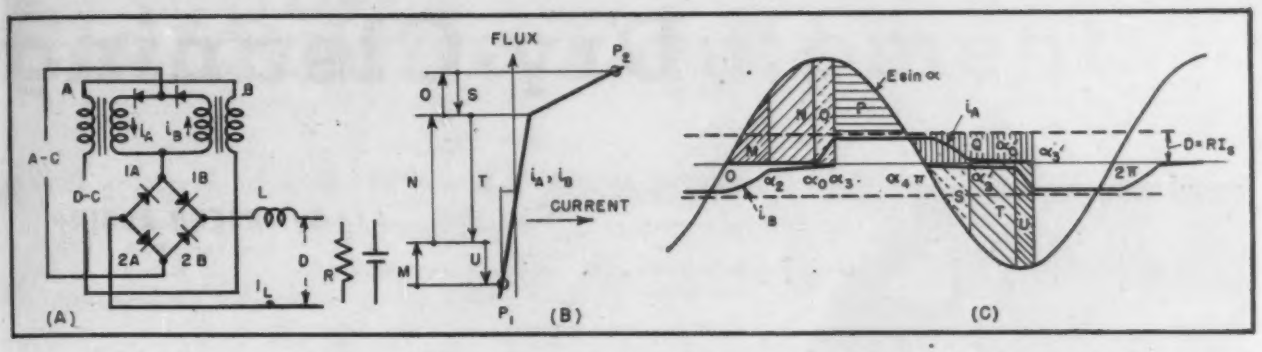

FIG. 5—Analysis like that of two-element transductor shows commutation of current from one element to the other

According to Fig. 5C the relation between the voltage areas is

$$N = T \text{ and } O = U = S = M \quad (4)$$

Furthermore, because the reactor voltage cannot contain a direct component

$$P = Q \quad (5)$$

By comparing the voltage areas between, for instance α_2 and α_3', the magnitude of the direct voltage D can be determined

$$D(\alpha_3' - \alpha_2) = D\pi = \int_{\alpha_2}^{\pi} E \sin\alpha \, d\alpha - P + Q \quad (6)$$

but from Eq. 5 and the relation

$$(1/\pi)\int_{\alpha_0}^{\pi} E \sin\alpha \, d\alpha = E_M - E_T$$

where E_M represents the mean value of the alternating voltage and E_T the mean value of the transductor voltage, Eq. 6 becomes

$$D = E_M - E_T \quad (7)$$

Thus the relation is of the first power, and not of the second as might be expected.

Dynamic Response

The preceding analysis has shown that the static conditions in a transductor are determined by the control current, which in effect governs the average flux. The average flux is also the deciding factor in determining how the transductor will momentarily follow the control current until the latter attains a new stationary value. However, the manner in which the control current behaves to a voltage impulse in the control circuit depends on the actual amplification and frequency. Different connections behave differently.

The scope of this article prohibits analyzing all connections, so the following discussion will be limited to the circuit of Fig. 1F. It is assumed that a voltage impulse Δd is impressed on the control winding, which, under steady-state conditions, would cause an alteration ΔI_s in the control current. At the same time the lowest value of flux would be changed from ϕ_1 to ϕ_2, both values being below saturation. The problem is to find the manner in which the load voltage D changes with time ($\Delta D = D_1 - D_2$).

The average load voltage during a half cycle corresponds to the difference between the supply and the transductor voltages so that

$$D_1 = E - 2N_v f(\phi_0 - \phi_1) \quad (8A)$$

$$D_2 = E - 2N_v f(\phi_0 - \phi_2) \quad (8B)$$

f representing the supply frequency, N_v the number of turns on the a-c winding. Hence

$$\Delta D = D_1 - D_2 = 2N_v f(\phi_2 - \phi_1) \quad (8C)$$

but the control current must change the average flux from ϕ_{1M} to ϕ_{2M} so

$$\phi_{1M} = (\phi_0 - \phi_1)/2 \quad (9A)$$

$$\phi_{2M} = (\phi_0 - \phi_2)/2 \quad (9B)$$

$$\Delta\phi_M = \phi_{1M} - \phi_{2M} = (\phi_2 - \phi_1)/2 \quad (9C)$$

If the fictitious inductance of one control winding is L_s and the number of control turns is N_s then

$$L_s = \frac{N_s \Delta\phi_M}{I_s} = N_s \frac{\phi_2 - \phi_1}{2\Delta I_s} \quad (10)$$

and the time constant of the complete transductor is

$$\tau = \frac{2L_s}{R_s} = N_s \frac{\phi_2 - \phi_1}{R_s/I_s} = \frac{N_s \Delta D(\phi_2 - \phi_1)}{2N_v f(\phi_2 - \phi_1)} \frac{1}{R_s \Delta I_s} \quad (11)$$

but because $R_s \Delta I_s = \Delta d$ Eq. 11 simplifies to[6]

$$\tau = (\Delta D/\Delta d)(N_s/N_v)(1/2f) \quad (12)$$

which gives the time constant for the rise in load voltage in response to a voltage step in the control circuit. Thus, if the amplification remains constant, the time constant can be reduced either by increasing the frequency of the supply voltage or by selecting a magnetic-core material possessing properties that allows N_s to be reduced. The three properties, power amplification, power sensitivity, and time constant, of a self-excited transductor depend on each other in such a way that one of them can be improved only at the expense of the other two. The rapidity of the transductor is limited by the fact that the control current cannot exert any influence on the transductor during the interval when any of the elements carry the main current; that is, between α_0 and π.

The development of the transductor techniques of which this article is a brief review has been carried forward especially by A. U. Lamm and U. H. Krabbe and by many collaborators. The authors are indebted to ASEA for permission to publish this article.

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Dry-Cleaning

By JOSEPH ALBIN
New York, N. Y.

FIG. 1—In well-ventilated working areas, a source of compressed air, gun, tray, Venturi fitting and a solvent can be used for dry cleaning of chassis

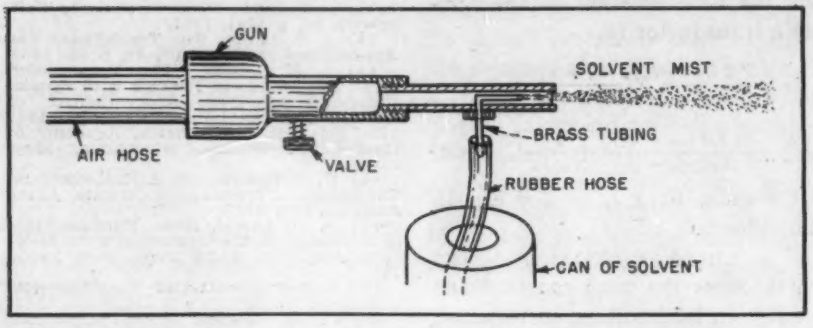

FIG. 2—Construction of simple fitting for air gun to provide fine spray of solvent under pressure

SOLVENT-SPRAY cleaning is one of the maintenance operations undergone by all aircraft and ground radio equipment that is sent to the American Airlines radio overhaul base at La Guardia Field, New York. Overhaul is scheduled after 90 days (average of 900 hours) of operation even though the equipment is operating perfectly. The types of electronic gear cleaned by the spray method include h-f and vhf communication units, adf receivers and indicators, marker, range, glide path and localizer receivers.

A member of the maintenance crew is shown in Fig. 1 going over the chassis of a ground transmitter in one of the hangars. He uses an improvised spray gun constructed as shown in principle in Fig. 2 and connected to a compressed-air line. Solvent contained in the can feeds to the nozzle of the air gun and is sprayed as a fine mist. Because of the pressure, hard to reach places such as capacitor plates and tube sockets are quickly cleaned.

The chassis is supported on blocks in a tray which serves to catch the dirty solvent. As this operation is done in an open space within the hangar, ventilation does not become a problem. To air-dry the equipment after cleaning, it is only necessary to lift the rubber hose out of the solvent can.

The nozzle for the air gun operates on the Venturi principle and consists of a section of metal tubing through which the solvent is aspirated by the air blast. A connection for a rubber hose for insertion in the liquid solvent is made on the side of the tubing a few inches from

Electronic Equipment

Rapid removal of soot, dirt and grime is accomplished with pressurized air and a solvent. Used at an airline radio overhaul base, the method can be adapted to maintenance of other electronic equipment

the end. Pressure control is obtained by means of the valve on the air gun.

With a nozzle orifice diameter of 0.125 inch, and air pressure of 40 pounds, the discharge of free air amounts to 12.4 cubic feet per minute. At 90 pounds pressure, the volume is slightly less than double this figure. For an orifice diameter of 0.25 inch, the volume is roughly quadrupled.

An installation suitable for factory applications is shown in Fig. 3. A large container of solvent is attached to the side of the booth and replenished as required. The solvent fluid reaches the nozzle through one of the flexible hoses; the other is for compressed air. Pressure is regulated and monitored by a valve and gage mounted in front of the booth. The cylindrical section contains a filter unit to remove moisture and scale. If driven out by high air pressure, the scale is likely to abrade or otherwise damage the radio equipment.

The booth is similar in all respects to the type used in spray painting, and is vented in the upper rear portion. Used solvent flows down a drain into a receptacle located below the booth.

In cleaning the radio unit shown, the air pressure is between 30 and 40 pounds. To dry, the operator turns a valve which shuts off the flow of solvent into the nozzle. In the overhaul shop, each man cleans the particular piece of equipment he is assigned to service.

A few changes are necessary when cleaning parts having more tenacious deposits of dirt, hence requiring higher air pressure, sometimes as high as 110 pounds. An extra long nozzle is used as well as protective gloves for the operator. Higher pressures can be safely applied to motors and heavy equipment.

Dry-cleaning solvents are of comparatively low inflammability and are nonexplosive. They follow in general the specification for Stoddard solvent, a standard fraction of petroleum, having a flash point between 100 and 105 F. At this temperature sufficient vapor is given off to flash momentarily on the application of a small flame.

In the Airlines laboratory, the chief characteristic checked in solvents is a minimum flash point of 110 F, determined by the Cleveland open-cup test. This is slightly higher than Stoddard solvent. Clarity and dryness are important factors. These flash points may be compared with that of ordinary gasoline at room temperature.

For regular production schedules, solvent-spray cleaning is best done for general comfort and health in a hood or booth that is vented to the outside atmosphere by means of a blower. Where the booth is lacking, the spraying should be carried out in an open and well-ventilated area. Ordinary fire extinguishers, such as those containing carbon tetrachloride, are precautionary equipment. A settling tank can be used for reclaiming a high percentage of the solvent.

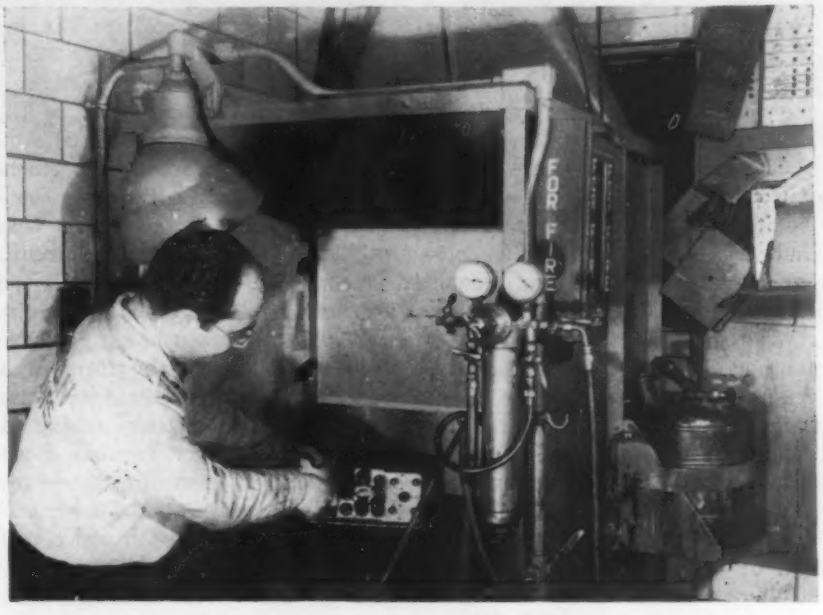

FIG. 3—Solvent spray booth for permanent installation in a factory, shop or laboratory. Fumes are vented to the outside air and additional equipment provided for control of air pressure, filtering and safety

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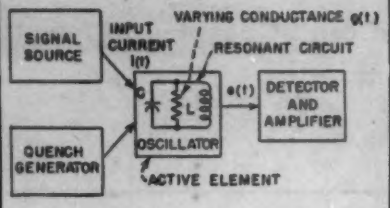
SUPERREGENERATIVE

By WILLIAM E. BRADLEY

Director of Research
Philco Corporation
Philadelphia, Pa.



$$e'' + P(t)e' + [\omega_0^2 + P'(t)]\,e = i'(t)/C \qquad (1)$$

where $P(t) = g(t)/C$ and $\omega_0^2 = 1/LC$

$$e'' + P(t)e' + \left[\omega_0^2 + \frac{P'(t)}{2} + \frac{P''(t)}{4}\right]e = 0 \qquad (2)$$

satisfied by $e = \exp -0.5 \times \int P dt \pm j\omega_0 t$

$$E(t) = (1/j\omega_0 C) \times \int_{-\infty}^{\infty} F(t,\tau) i'(\tau) e^{-i\omega_0 \tau} d\tau \qquad (3)$$

which for $i(t) = I\cos\omega_s t$, becomes

$$E(t) = (I/2C) \times \int_{-\infty}^{\infty} F(t,\tau) e^{j(\omega_s - \omega_0)\tau} d\tau \qquad (4)$$

$$F(t,\tau) = \begin{cases} 0 \text{ for } \tau > t \\ \exp -0.5 \int_{\tau}^{t} P(t)dt \text{ for } \tau < t \end{cases} \qquad (5)$$

FIG. 1—Chief element of superregenerative detector is resonant circuit with varying damping; the equations describe it

AN investigation into the operating mechanism of the superregenerative detector, has used physical reasoning and results of measurements.

The specific object of the investigation was to develop a theory that would identify the factors controlling selectivity, optimum quenching, signal-noise ratio, and account for the difficulty of reproducing a given response from one design to another. Because most superregenerative detectors combine in one tube at least four distinct functions, it is not surprising that the behavior of the circuit is complex.

A superregenerative detector, the elements of which are shown in Fig. 1, ordinarily consists of an oscillator having a resonant circuit tuned to the frequency of the desired signal. This circuit is fed from an r-f stage, converter, or antenna, which can be considered a generator of current $i(t)$. The oscillator is caused to operate intermittently by means of a quenching signal supplied from an auxiliary oscillator or from low-frequency oscillation of the same tube. This quenching action can be represented by a varying conductance $g(t)$. The combination of resonant circuit and varying conductance constitute the active element. In addition there are the auxiliary elements, an oscillation detector and an audio or video amplifier. An automatic regeneration control feedback from beyond the oscillation detector to the active element may also be included.

The circuit performs four fundamental operations in sequence: (1) Quenching erases the effect of the previous cycle of operation, clearing the circuit for reception of new impressions; this is done by cutting off the oscillating tube or by damping the circuit. The varying conductance is positive during quenching. (2) Reception takes place when the incoming wave sets up a signal in the circuit as the quenching is withdrawn. (3) Amplification begins when the quenching is sufficiently withdrawn (conductance made negative) so that oscillations will grow in the circuit. This action continues until the overload level is reached or the circuit is again quenched. (4) Detection, usually in the form of a change in oscillator grid or plate current and sometimes using a separate crystal or vacuum diode or a change in quenching rate, produces an output that varies according to the rapidity with which full amplitude of oscillation is reached, and depends on the principle that the stronger the incoming signal the sooner the oscillation will reach full strength, usually several volts. At the end of this operation the varying conductance may fall to zero and the oscillations cease to grow, but nevertheless the requisite energy is delivered to the detector and amplifier.

Of the four operations, least is generally understood of the reception action. It is not obvious at what instant and in what manner the forced oscillation of the circuit produced by the incoming signal changes to free oscillation of the resonant circuit. To determine this and other circuit actions, an approximate solution of the differential equation of a tuned circuit with varying damping was made. Another rigorous approach, based on the superposition integral, has verified the results and indicated the trivial nature of the error in the approximate solution.

Reception and Amplification

To obtain a detailed picture of the behavior of the active element during reception and amplification of an incoming signal consider that a current $i(t) = I \exp j\omega_s t$ is continuously applied. At negative time (during the quenching operation) the varying conductance $g(t)$ has a large positive value; it varies in some manner through zero at $t = 0$ to a generally negative value for positive values of t. The problem is to find the level of oscillation during the amplification operation.

The problem involves the solution of a linear second order differential equation with the coefficient of the first derivative varying with time. This is Eq. 1 (Fig. 1); the primes indicate differentiation with respect to time. The instantaneous voltage on the resonant circuit is $e(t)$; incoming signal is $i(t)$.

The rigorous solution of Eq. 1 is difficult to obtain and use because, to be mathematically complete, it

DETECTION THEORY

Operation of the superregenerative detector is developed, leading to the concept of a time aperture function. Bandwidth, signal-noise ratio, and other circuit properties are shown to depend on this function, whose values in turn depend on the quenching waveform

must include the effect of the resistance on the resonant frequency and all of the phenomena that hold for large values of $P(t)$, the damping factor, including the transition between oscillating and nonoscillating states. For present purposes such a solution is unnecessary because, in the practical case $P(t) \ll \omega_0^2$ and, for quench frequencies low compared to the resonant frequency $P'(t) \ll \omega_0^2$.

Under these conditions a very similar second order equation (with its right hand member zero), Eq. 2, can be used for comparison. The first two coefficients of Eq. 2 are identical with those of Eq. 1 and the third is negligibly different; hence, over a limited time, the solutions of the two equations cannot be very different in nature. In fact in the practical case of a high-frequency superregenerative detector the third coefficients of the two equations differ by less than the error in measuring ω_0. For the purpose of this analysis the solution of the comparison equation Eq. 2 differs negligibly from the correct solution of the reduced or homogenous form of the circuit equation.

Knowing the two functions e_1 and e_2 that satisfy the reduced equation, the complete solution of the equation with right hand member can be found by the method of variation of parameters (Lester R. Ford, "Differential Equations", McGraw-Hill Book Co., New York, 1933, p 75.) The solutions are Eq. 3, 4 and 5.

Equations 3, 4 and 5 embody a complete solution to the problem. The function $F(t,\tau)$ is called the time aperture function and, as will be shown, is of basic importance in describing superregenerative detection. Equation 3 states that the voltage envelope amplitude across the resonant circuit at a particular instant of observation, t, depends on an integral of the product of the time aperture function and the input signal, the integration being performed over the preceding time, τ, so that each time element of input signal contributes to the output with a relative importance determined by the value of the time aperture function. Usually the time aperture function has one very large peak, at the moment when the damping passes through zero, and falls rapidly to small values on either side of this moment. Therefore the incoming signal at the moment of zero damping has the greatest effect on the output. This behavior gives rise to the sensitive period of the detector.

Equation 4 expresses the output due to a carrier that remains substantially constant in frequency and amplitude during one quench cycle. The integral is of the same form as the Fourier analysis integral that gives the frequency spectrum of a pulse. As a consequence the time aperture function is related to the selectivity curve of the superregenerative detector in the same way that the waveform of the envelope of a pulsed carrier is related to its spectrum. Thus, for example, a narrow time aperture function causes a broad band receiver and a broad function causes a narrow acceptance band.

The time aperture function is given by Eq. 5 provided the variation of damping with time is known; that is, when $P(t)$ is known. In geometrical terms, if a function of time is drawn having everywhere a slope of $0.5P(t)$ and intersecting the time axis at time t of observation of the resonant circuit voltage, the curve for time prior to t is the natural logarithm of the time aperture function. This process is illustrated in Fig. 2.

Suppose that a sine wave is used for quenching, and that it cuts off the oscillator tube for a large part of the cycle; this sort of operation is usual in some of the older separately quenched superregenerative detectors. Then $P(t)$, the exponent gand $F(t,\tau)$ are shown in Fig. 2B.

By sketching the form of $F(t,\tau)$ for various values of t it is discovered that the area under $F(t,\tau)$ increases rapidly with increasing t, showing that $E(t)$ is growing rapidly with time during the amplification phase. It is also found that the peak of $F(t,\tau)$ as a function of τ occurs at the instant that

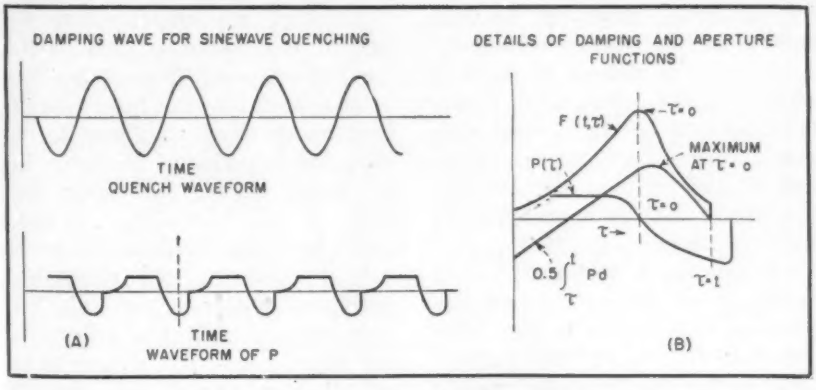


FIG. 2—Variation with time of the damping and aperture functions depends on the form of the quenching wave

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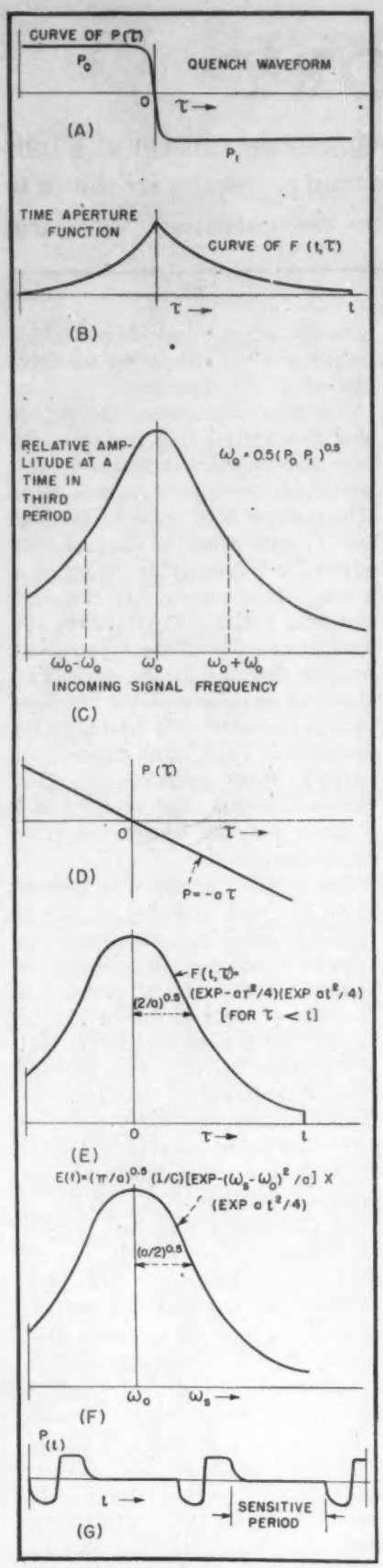

FIG. 3—Knowing the time variation of the damping, the aperture function and pass band can be determined. Optimum quenching waveform is given at (G)

$P(t)$ passes through zero.

The theory developed in the foregoing analysis can be applied exactly in a few interesting cases. Suppose that a square quenching wave is used such that $P(t)$ is positive and equal to P_0 prior to $\tau = 0$ and that it is negative and equal to $-P_1$ thereafter. The quench waveform and time aperture function for this case are shown in Fig. 3A and B. The relative amplitudes of the signal in the amplification phase are also shown (Fig. 3C); this later curve is effectively the selectivity curve of the detector.

For a sensitive, narrow-band detector with a square quenching wave, $-P_1$ should be made as small as is consistent with the chosen quench frequency. For thorough quenching in a short interval P_0 must be large.

Another practical case is that of linearly changing $P(t)$. The commonly used sine wave quenching wave causes $P(t)$ to change from positive to negative nearly linearly. The bandwidth and time aperture function $F(t,\tau)$ depend on the rate of change of $P(t)$. If $P(t)$ has been changing linearly in a negative direction since $t = -\infty$ and at $t = 0$ passes through zero, the voltage $E(t)$ at time t due to an input $I \cos \omega_s t$ can be found as outlined at Fig. 3D through 3F. For this special case both the time aperture and the frequency response have the shape of a probability function.

Requirements for Optimum Quenching

The almost proverbial poor signal-noise ratio of superregenerative detectors is mostly due to the short effective duration of the time aperture function. In most cases the time aperture function has an effective duration, measured between points of half-peak sensitivity, much less than a tenth of the total quench period. Statistical theory indicates that the signal-noise ratio should vary directly as the square root of the ratio of the effective duration of the time aperture to the total quench cycle duration.

The narrowest band and greatest sensitivity as well as the best signal-noise ratio appear to be obtainable when $P(t)$ has a large positive value during the quenching period (first operation), which is made as short as is consistent with thorough quenching, followed by a value of zero during the entire reception period (second function), which is made as long as possible. The amplification (third function) and detection (fourth function) periods should be as short as is practical. To achieve this result, $P(t)$ should become quite negative so as to amplify quickly the voltage existing at the end of the reception period to a usable level. The required waveform is shown in Fig. 3G.

Certain additional precautions must also be observed in designing superregenerative detectors. The quenching must be complete, otherwise remnants of oscillation persist from the preceding cycle, spoiling the sensitivity of the receiver. Ringing or spurious modes of resonance associated with r-f chokes, quenching circuit coils, or other components can interfere with the quenching, retaining a remnent signal to compete with the new incoming one. Typical symptoms of this difficulty appear when a sharply resonant circuit such as a wavemeter is momentarily held close to the active element. Another effect, usually serious only in low-frequency superregenerative detectors, is shock excitation of the active element by the quenching wave. This action reduces the sensitivity; it is eliminated by restricting the frequency content of the quench.

A simple way of testing for the presence of any of these difficulties is to examine the shape of the selectivity curve with a weak incoming signal. The selectivity curve should be smooth and single peaked. Any of the above difficulties will cause peaks separated by an interval equal to the quench frequency.

Although superregenerative detectors may take a bewildering number of special forms depending upon application, the theory developed above has been found to explain the behavior of all forms investigated during the past five years in this laboratory. In each case the development centered around obtaining the prescribed aperture function. Once this had been accomplished the selectivity and signal-noise ratio measured on the detector agreed substantially with the calculations.

SUPERREGENERATOR DESIGN

Gain and selectivity of superregenerative receivers can be predicted by the principles that are developed. Circuit operation and the effects on operating characteristics of changing various components are explained. Effects of specific quenching waveshapes are discussed

By ALAN HAZELTINE, D. RICHMAN and B. D. LOUGHLIN

Hazeltine Electronics Corp., Little Neck, N. Y.

A SUPERREGENERATOR consists of a resonant circuit and an oscillator or regenerator tube, as shown in Fig. 1A. The resonator has a positive damping G_+ consisting of the inherent and coupled losses of the tuned circuit. The resonator is also periodically supplied with an effective negative conductance ($G_- - G_+$) by regenerator tube, which is switched on and off by a quenching voltage to produce this effect.

Much prewar information on this circuit is vague, particularly that concerning gain and selectivity. Extensive war-time application of superregeneration in IFF equipment required a thorough investigation. Late in 1942, H. A. Wheeler developed the basic concepts that lead to a clarification of the characteristics of this device. A summary of this theory is given and it is shown how it can be used as a guide in designing superregenerative receivers.

The Superregenerator

In the circuit described above, transient oscillations, excited by a signal in the tank (Fig. 1B), build up exponentially during the period of negative conductance. When the

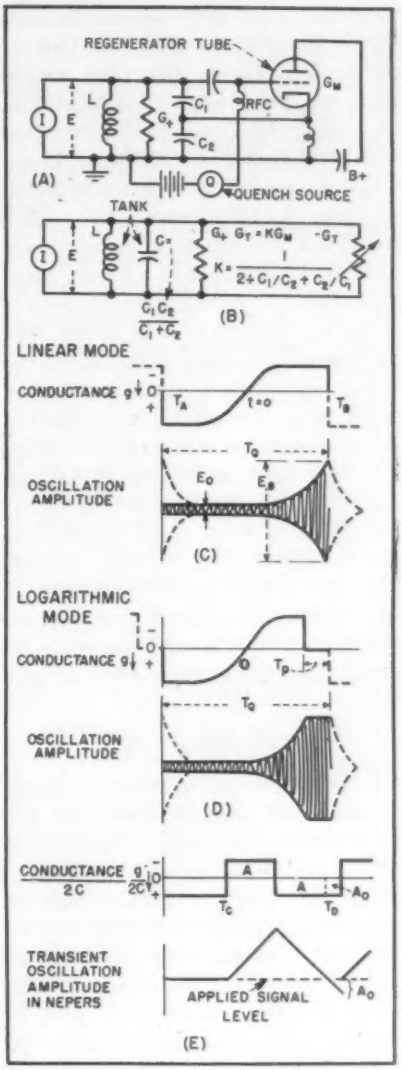

FIG. 1—Superregenerative circuit (A) and equivalent circuit (B) and relation of oscillation amplitude to waveshape of conductance (C), (D) and (E) under various conditions

INDEPENDENT INVESTIGATIONS

This and the preceding article present similar material. One might ask why the duplication. There are two reasons:

(1) Simultaneous investigations of the superregenerative circuit were made, each deserving recognition through publication.

(2) Use of this circuit has been hampered by lack of an adequate explanation of its operation. The subject might still be considered controversial had independent investigators not come to similar conclusions. It is important to progress that there be duplication of effort so the investigators will constantly be checking each other's results.

Now that some agreement has been reached on theory and design factors, numerous applications of the superregenerative method for obtaining stable and extremely high amplification will be found.

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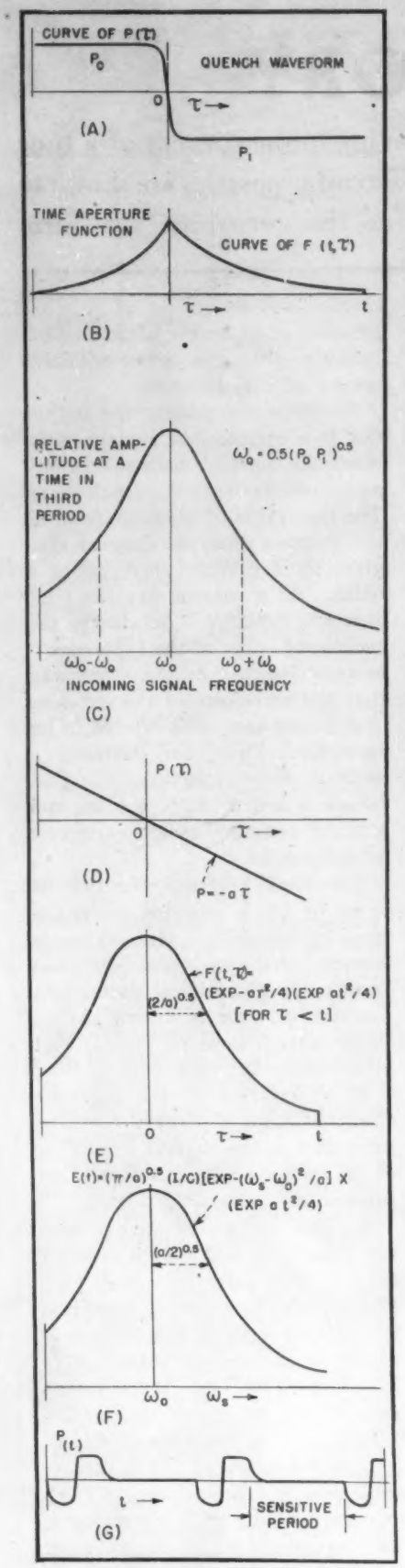

FIG. 3—Knowing the time variation of the damping, the aperture function and pass band can be determined. Optimum quenching waveform is given at (G)

$P(t)$ passes through zero.

The theory developed in the foregoing analysis can be applied exactly in a few interesting cases. Suppose that a square quenching wave is used such that $P(t)$ is positive and equal to P_0 prior to $\tau = 0$ and that it is negative and equal to $-P_1$ thereafter. The quench waveform and time aperture function for this case are shown in Fig. 3A and B. The relative amplitudes of the signal in the amplification phase are also shown (Fig. 3C); this later curve is effectively the selectivity curve of the detector.

For a sensitive, narrow-band detector with a square quenching wave, $-P_1$ should be made as small as is consistent with the chosen quench frequency. For thorough quenching in a short interval P_0 must be large.

Another practical case is that of linearly changing $P(t)$. The commonly used sine wave quenching wave causes $P(t)$ to change from positive to negative nearly linearly. The bandwidth and time aperture function $F(t,\tau)$ depend on the rate of change of $P(t)$. If $P(t)$ has been changing linearly in a negative direction since $t = -\infty$ and at $t = 0$ passes through zero, the voltage $E(t)$ at time t due to an input $I \cos \omega_s t$ can be found as outlined at Fig. 3D through 3F. For this special case both the time aperture and the frequency response have the shape of a probability function.

Requirements for Optimum Quenching

The almost proverbial poor signal-noise ratio of superregenerative detectors is mostly due to the short effective duration of the time aperture function. In most cases the time aperture function has an effective duration, measured between points of half-peak sensitivity, much less than a tenth of the total quench period. Statistical theory indicates that the signal-noise ratio should vary directly as the square root of the ratio of the effective duration of the time aperture to the total quench cycle duration.

The narrowest band and greatest sensitivity as well as the best signal-noise ratio appear to be obtainable when $P(t)$ has a large positive value during the quenching period (first operation), which is made as short as is consistent with thorough quenching, followed by a value of zero during the entire reception period (second function), which is made as long as possible. The amplification (third function) and detection (fourth function) periods should be as short as is practical. To achieve this result, $P(t)$ should become quite negative so as to amplify quickly the voltage existing at the end of the reception period to a usable level. The required waveform is shown in Fig. 3G.

Certain additional precautions must also be observed in designing superregenerative detectors. The quenching must be complete, otherwise remnants of oscillation persist from the preceding cycle, spoiling the sensitivity of the receiver. Ringing or spurious modes of resonance associated with r-f chokes, quenching circuit coils, or other components can interfere with the quenching, retaining a remnent signal to compete with the new incoming one. Typical symptoms of this difficulty appear when a sharply resonant circuit such as a wavemeter is momentarily held close to the active element. Another effect, usually serious only in low-frequency superregenerative detectors, is shock excitation of the active element by the quenching wave. This action reduces the sensitivity; it is eliminated by restricting the frequency content of the quench.

A simple way of testing for the presence of any of these difficulties is to examine the shape of the selectivity curve with a weak incoming signal. The selectivity curve should be smooth and single peaked. Any of the above difficulties will cause peaks separated by an interval equal to the quench frequency.

Although superregenerative detectors may take a bewildering number of special forms depending upon application, the theory developed above has been found to explain the behavior of all forms investigated during the past five years in this laboratory. In each case the development centered around obtaining the prescribed aperture function. Once this had been accomplished the selectivity and signal-noise ratio measured on the detector agreed substantially with the calculations.

SUPERREGENERATOR DESIGN

Gain and selectivity of superregenerative receivers can be predicted by the principles that are developed. Circuit operation and the effects on operating characteristics of changing various components are explained. Effects of specific quenching waveshapes are discussed

By ALAN HAZELTINE, D. RICHMAN and B. D. LOUGHLIN

Hazeltine Electronics Corp., Little Neck, N. Y.

A SUPERREGENERATOR consists of a resonant circuit and an oscillator or regenerator tube, as shown in Fig. 1A. The resonator has a positive damping G_+ consisting of the inherent and coupled losses of the tuned circuit. The resonator is also periodically supplied with an effective negative conductance ($G_- - G_+$) by regenerator tube, which is switched on and off by a quenching voltage to produce this effect.

Much prewar information on this circuit is vague, particularly that concerning gain and selectivity. Extensive war-time application of superregeneration in IFF equipment required a thorough investigation. Late in 1942, H. A. Wheeler developed the basic concepts that lead to a clarification of the characteristics of this device. A summary of this theory is given and it is shown how it can be used as a guide in designing superregenerative receivers.

The Superregenerator

In the circuit described above, transient oscillations, excited by a signal in the tank (Fig. 1B), build up exponentially during the period of negative conductance. When the

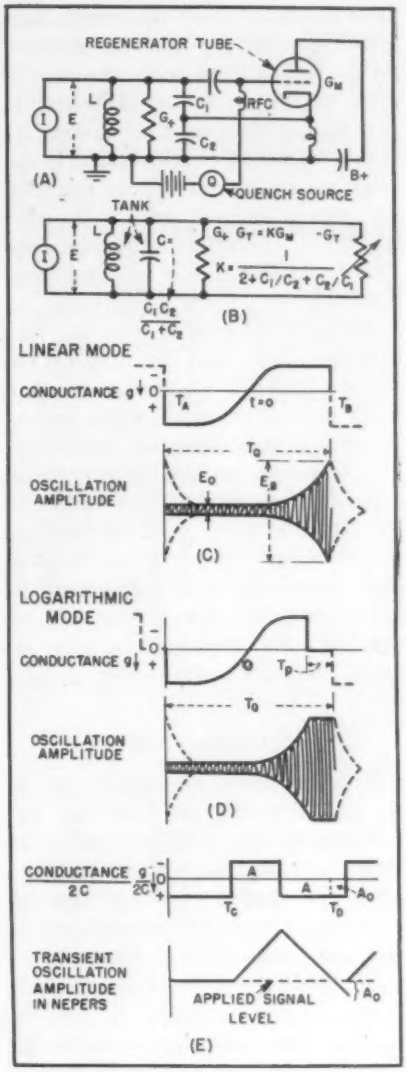

FIG. 1—Superregenerative circuit (A) and equivalent circuit (B) and relation of oscillation amplitude to waveshape of conductance (C), (D) and (E) under various conditions

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quench voltage turns off the regenerator tube, a period of positive conductance results during which the oscillations are quenched. In most applications it is desirable for the transient oscillations of one quench cycle to almost completely die out so that the transient of the next quench cycle is started mainly by the applied signal.

In the linear mode of operation (Fig. 1C) the regenerator tube is turned off and oscillations are quenched before they reach saturation. The oscillations at the end of the negative conductance period, which are generally fed to a peak detector, are linearly related to the applied signal amplitude.

In the logarithmic mode of operation (Fig. 1D) the regenerator tube stays on until the oscillations reach saturation. The duration of saturation varies with the amplitude of the applied signal, giving, for separately quenched operation, a saturation pulse width that is approximately a logarithmic function of signal amplitude. For self-quenched operation a quench rate that is approximately a logarithmic function of signal amplitude results.[1] Detection of a-m in the logarithmic mode may be obtained by using a separate averaging detector or by using the variations in the regenerator tube electrode currents. The transient oscillation energy of a logarithmic-mode superregenerator has also been used to feed an f-m detector.[2] For studies of gain and selectivity it is convenient to ignore the detection action, and to consider the superregenerator as merely a carrier-frequency amplifier.

Calculating Gain

Action of the superregenerator as an amplifier can be described by considering the tank with its inherent and coupled positive conductance as being shunted by a periodically varying negative conductance, representing the regenerator tube. A general shape of conductance-time variation is shown for the two operating modes in Fig. 1C and D.

For calculating gain and selectivity, it is convenient to consider that a cycle of quench operation starts at T_A when the oscillations of the previous cycle are being damped out and the input current I begins to establish a normal signal in the tank, and that the cycle ends at T_B when the oscillations have again built up to maximum amplitude.

The superregenerative transient oscillation resulting from a short r-f pulse at $t = 0$ (when $g = 0$) has an amplitude at time T_B of

$$E_B = E_0 \exp\left(-\frac{1}{2c}\int_0^{T_B} g\,dt\right) \qquad (1)$$

where E_0 is the amplitude at $t = 0$ and E_B is the amplitude at T_B. It is convenient to express the ratio of the superregenerative transient amplitude to the applied signal amplitude as a gain A in nepers (one neper equals approximately 8.7 db) so that

$$A = \ln\frac{E_B}{E_0} = -\frac{1}{2C}\int_0^{T_B} g\,dt \qquad (2)$$

Thus, $1/2C$ times the area under the negative conductance-time curve between $t = 0$ and $t = T_B$ represents the gain in nepers to a short r-f pulse applied at $t = 0$ and measured at $t = T_B$.

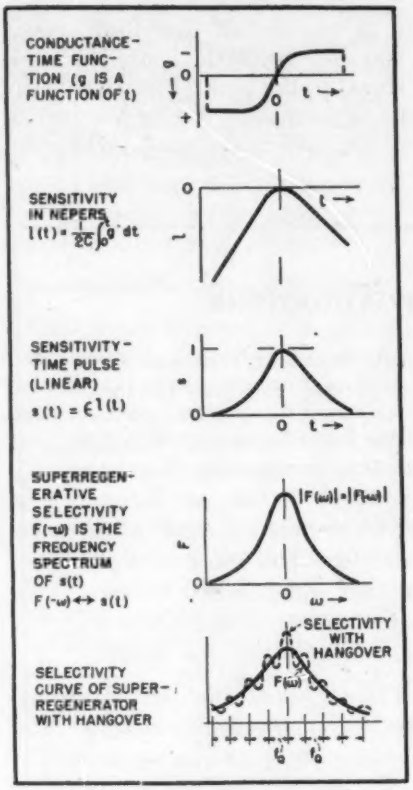
CONDUCTANCE-TIME FUNCTION (g IS A FUNCTION OF t)
SENSITIVITY IN NEPERS
SENSITIVITY-TIME PULSE (LINEAR)
SUPERREGENERATIVE SELECTIVITY F(ω) IS THE FREQUENCY SPECTRUM OF s(t)
SELECTIVITY CURVE OF SUPERREGENERATOR WITH HANGOVER
SELECTIVITY WITH HANGOVER

FIG. 2—Steps in the development of selectivity from waveform of conductance, as described in text, and, at bottom, effect of hangover on selectivity

For the linear mode the total superregenerative gain is given by integrating the total negative conductance area. For the logarithmic mode the effective superregenerative gain is obtained by integrating the negative conductance area up to the time of saturation. This is illustrated in Fig. 1D where T_P is the period of the constant amplitude (saturation) oscillations of the logarithmic mode of operation.

The superregenerative gain just described is not the total gain for a continuous carrier at the frequency of the resonator. Some further gain results because the r-f signal is present during the entire quench cycle. This produces a regenerative gain R which is generally considerably less than the superregenerative gain.

Sensitivity Limitations

The manner of decay of the oscillations during positive conductance is similar to the transient build-up during negative conductance, and the same equations hold for the transient amplitude in the positive conductance area. With repetitive quench, as shown in Fig. 1E, the net transient amplitude at T_D due to the energy remaining in the tank from the previous transient of oscillation initiated in the tank at T_C is given approximately by $1/2C$ times the net area under the conductance-time curve between T_C and T_D. *Thus, for the transient hangover to be less than the applied signal, the net area over a complete quench cycle must be positive.* This excess damping, shown as A_0 in Fig. 1E, should be at least 3 to 5 nepers for most applications.

Sensitivity of a superregenerative receiver is determined by the minimum usable signal level. For the logarithmic mode, sufficient superregenerative gain is obtained to amplify thermal noise to saturate the regenerator tube. In this case the sensitivity is limited by the signal-noise ratio or by the signal level necessary to overcome hangover.

In a linear mode superregenerator, sensitivity may be limited by insufficient gain, as well as by signal-noise ratio or hangover. This is particularly true in applications using a very high quench rate, low-transconductance regenerator

tubes, or high-capacitance resonators.

If a short r-f pulse is applied to a superregenerator, highest gain is realized if the pulse is applied when the conductance passes through zero going from positive to negative. If applied later, there is less remaining negative conductance area and thus less gain. If applied earlier, the oscillations decay again, giving less gain. Thus, the superregenerator can be considered to have a sensitivity which varies during the quench cycle, having a maximum at the time when $g = 0$ and is going from plus to minus.

Variation of sensitivity in nepers with time can be found directly from the conductance-time function, and from this a linear sensitivity-time pulse can be calculated, as in Fig. 2. The magnitude of the superregenerative selectivity curve has the same shape as the frequency spectrum of this sensitivity-time pulse. The corresponding frequency spectrum can be found by Fourier analysis or by Campbell and Foster's tables.[8] The four steps, ignoring effects of hangover and assuming high gain, in finding the bandwidth of a superregenerator with a known variation of conductance with time, are shown in Fig. 2; at the bottom of the figure the response in the presence of hangover is shown.

Design Data

To illustrate how these steps might be applied, consider the design of a superregenerator that is quenched as in Fig. 1A. From an assumed quench waveshape and a knowledge of the variation in transconductance with grid bias (as obtained from published tube data), the variation of transconductance with time can be found. By applying the equations of Fig. 1B, the variation of G_T can be found. This is subtracted from an assumed (or known) value of G_+ for the resonator, giving the net conductance-time function needed for applying the steps of Fig. 2. The sensitivity function $l(t)$ in nepers can be obtained by integrating (graphically, if necessary) the conductance-time function and multiplying by $1/2C$. The linear sensitivity-time pulse $s(t)$ is obtained by exp $l(t)$, where $l(t)$ is conveniently taken to be zero at $t = 0$. The superregenerative selectivity shape is found from the frequency spectrum of $s(t)$. If $s(t)$ is not found in Fourier transform tables, an approximate answer may be obtained by graphical Fourier analysis.

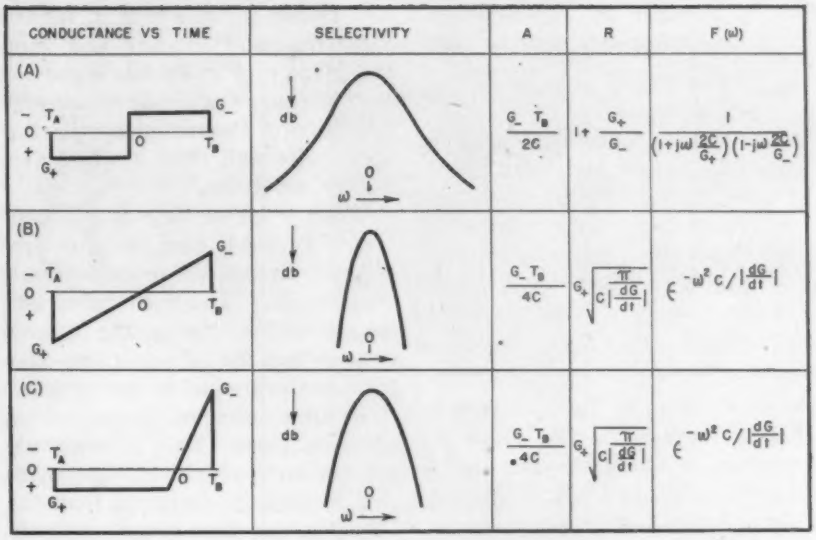

FIG. 3—Conductance waveform controls selectivity, as these specific examples show

If it is desired to calculate the selectivity of an existing superregenerator, it may be convenient to find the plate-current waveform of the regenerator tube (by inserting a small resistor in the plate circuit and observing the quench-frequency voltage waveform across it on an oscilloscope). Then the selectivity can be calculated as before.

Equations for Gain and Selectivity

The variation in superregenerative sensitivity with time means that the effect of the current supplied to the resonator varies with time. This is exactly equivalent to a variation in input current amplitude with time. It can be shown that the magnitude of the superregenerative selectivity response characteristic is equivalent to that of an unvaried and undamped resonator to which an a-m signal is applied. The spectrum of that a-m signal is continuous because each cycle of quench is independent of the others, if hangover is negligible. The selectivity characteristic of the superregenerator is exactly equivalent to the frequency spectrum of the amplitude modulated signal, or of the sensitivity pulse.

The sensitivity pulse is defined as

$$s(t) = \exp\left(\frac{1}{2C}\int_0^t g\,dt\right) \qquad (3)$$

where this relation holds for $T_A \leqq t \leqq T_B$, and $s\ (t) = 0$ outside of these limits.

The gain of the superregenerator, H, is defined as the ratio of the voltage existing at the peak of a superregenerative cycle to the voltage which would be developed across the tank at resonance if the conductance had remained at the value G_+. That is

$$H = E_B/(I/G_+) \qquad (4)$$

It can then be shown (for example, by conservation of energy or by superposition of the effects of a series of impulses) that

$$H = \exp(A)\,\frac{G_+}{2C}\times$$

$$\int_{T_A}^{T_B} \exp\left(\frac{1}{2C}\int_0^t g\,dt + j\omega t\right) dt \qquad (5)$$

If hangover is ignored and the superregenerative gain is large, Eq. 5 reduces to

$$H = \exp(A)\,\frac{G_+}{2C}\int_{-\infty}^{+\infty} s(t)\exp(j\omega t)\,dt \qquad (6)$$

Equation 6, which ignores end effects, indicates that the selectivity of a superregenerator can be found from the inverse Fourier transform of the sensitivity-time pulse. The factor, exp A, in Eq. 6 is the superregenerative transient gain where

$$A = -\frac{1}{2C}\int_0^{T_B} g\,dt \qquad (7)$$

The remaining factor, evaluated at resonance, defines the added gain

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that is obtained by regeneration. The regenerative gain ratio is

$$R = \frac{G_+}{2C} \int_{-\infty}^{+\infty} s(t)dt \qquad (8)$$

As before, these steps have ignored effects of hangover and assume that the superregenerative gain is large.

Effects of hangover can be computed from the net attenuation, A_0, and phase shift per cycle, exp $(-A_0 - j\ \omega\ T_Q)$. The resulting selectivity is

$$S = F(\omega)/[1 - \exp(-A_0 - j\omega T_Q)] \qquad (9)$$

where F (ω) is the selectivity ignoring hangover. The curve at the bottom of Fig. 2, showing hangover, is plotted to a linear scale; the peaks are very nearly separated by $F_Q = 1/T_Q$ and the troughs are halfway between.

Effects of Special Waveshapes

Figure 3 gives examples of three conductance-time curves with their corresponding selectivities as calculated by the foregoing method, as well as the equations for superregenerative gain A, regenerative gain R and selectivity $F(\omega)$, ignoring hangover and end effects.

In the case of symmetrical squarewave quench (Fig. 3A), a selectivity equal to that of two cascaded, isolated single-tuned circuits (one having conductance G_+, the other G_-) is obtained. When $|G_-| = G_+$ the equivalent phase characteristic of the selectivity has no phase distortion. This distortionless phase characteristic is produced by all conductance-time functions which have skew symmetry about $g = 0$ (Fig. 3A and 3B). When gain A is large, departure from exact skew symmetry in regions remote from $g = 0$ can be neglected.

The triangular conductance waveform of Fig. 3B produces a selectivity having the form of a probability curve. (A probability curve plotted to a db scale forms a parabola.)

The conductance waveshape of Fig. 3C is similar to that found in the usual self-quenched superregenerator, particularly those using grid quench and having the grid leak returned to a positive bias. This waveform produces a selectivity following a probability curve, but considerably wider than that of Fig. 3B. The reason for this is that, for the same quench frequency and gain, the shape of Fig. 3C has a greater rate of change of conductance with time, giving a narrower sensitivity-time pulse and thus a wider frequency spectrum.

When a converting superregenerator is used, such as the Fre-Modyne circuit, an unusual result is obtained. The conversion efficiency varies during the quench cycle so that the r-f sensitivity-time pulse is the product of the i-f sensitivity-time pulse and the conversion efficiency pulse. This generally results in an r-f sensitivity-time pulse that is slightly narrower than the i-f pulse, and thus gives a slightly wider r-f bandwidth than i-f bandwidth.

In the foregoing discussion it has been assumed that the resonant frequency of the superregenerative tank circuit does not vary during the quench cycle. This gives symmetrical selectivity curves. If the superregenerative tank frequency varies appreciably during the period when the sensitivity-time pulse has significant amplitude, then a result much like a combination of simultaneous a-m and f-m is obtained, which can produce unsymmetrical selectivity curves.

Practical Considerations

It can be shown that the shape of the selectivity curve near the nose of the curve is determined mainly by the shape of the conductance-time curve near the time when $g = 0$. If the conductance waveshape is approximately a straight line in the vicinity of $g = 0$, then the selectivity curve is a probability curve to approximately as many db of attenuation as are represented by the superregenerative gain obtained during the linearly sloping part of the conductance wave form. This leads to the useful approximation that *the total bandwidth at one neper (8.7 db) from the peak is*[4]

$$f_w = (1/\pi)\ \sqrt{(1/c)\,|dG/dt|} \qquad (10)$$

where dG/dt is the slope of the conductance-time curve at $g = 0$.

In a separately quenched superregenerator, Eq. 10 shows that, in general, if the quench voltage amplitude is increased, the selectivity curve will become wider. Also, if the quench voltage frequency is reduced, keeping the same waveshape, that the selectivity curve will become narrower. However, if the quench amplitude is increased, or the frequency decreases, the available superregenerative gain will be increased, producing more total gain for a linear mode operation or producing an earlier saturation in logarithmic mode. *Thus for a given quench waveshape, and for a specified superregenerative gain, the narrowest selectivity is obtained by using the lowest possible quench frequency.* However the minimum quench frequency should be at least equal to twice the maximum modulation frequency of the received signal.

The question frequently arises of how to measure the selectivity of an existing superregenerator. Conventional methods may be applied in certain cases, but are generally inadequate. With certain types of superregenerators the problem is like measuring the selectivity of a conventional receiver having a very flat avc that cannot be disconnected. The following method is suggested as being applicable to substantially all forms of superregenerators normally used.

The audio output noise of the receiver, without an applied signal, is measured by an output meter (rms type preferred). A signal is applied at resonance and adjusted in level until the noise is suppressed by some convenient amount such as 10 or 20 db. Then the signal is detuned and readjusted in level until the noise is suppressed by the same amount. The difference between the two levels is the attenuation or selectivity at the detuned frequency. By this method of constant noise suppression, the complete selectivity curve may be measured (assuming an adequate signal generator) to as much as 80 to 100 db of attenuation.

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(2) H. P. Kalmus, Superregeneration—Its Possibilities and Limitations, *Proc. IRE*, Oct. 1944.

(3) Bell Telephone System Monogram B-584, Fourier Integrals for Practical Applications.

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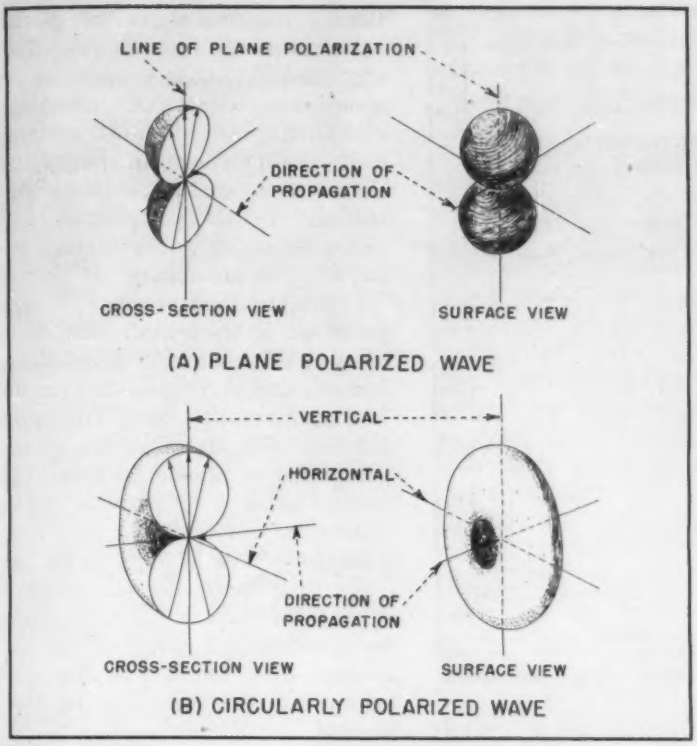
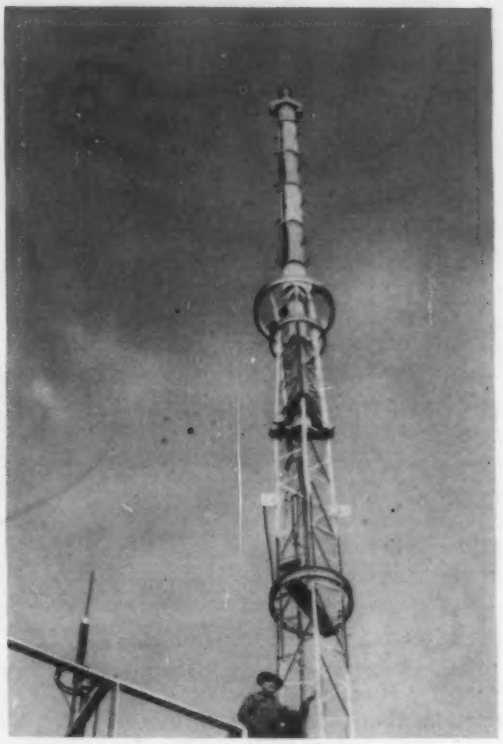


FIG. 1—Reception patterns of half-wave dipole in plane and circularly polarized fields



Circularly polarized antenna in use by radio station WHKX

Circular Polarization in F-M Broadcasting

Experimental field intensity measurements substantiate theoretical advantages to be gained over plane polarization. The high-gain omnidirectional broadcast transmitting antenna described allows most convenient location of home receivers

By CARL E. SMITH
Vice President in Charge of Engineering
United Broadcasting Co.
Cleveland, Ohio

and ROBERT A. FOUTY
Research Associate
Antenna Laboratory of
The Ohio State University
Research Foundation
Columbus, Ohio

MORE than two years ago the United Broadcasting Company initiated an experimental program to investigate the use of circular polarization for f-m.

The early experimental work was carried on with a prototype circular-polarization antenna consisting of a vertical half-wave dipole and a horizontal loop, mounted on the same vertical axis. A report covering this work was furnished to the Federal Communications Commission in October 1946.[1,2] Within 30 days the Commission had amended the Standards of Good Engineering Practice to permit the addition of a vertical component having the same magnitude as the horizontal component and thus making it possible to supply the service area with a diversely polarized signal from a circularly polarized f-m broadcasting antenna by radiating twice the power of either component operating alone.[3]

During the past year field measurements have been made on W8XUB and WHKX in Cleveland to determine quantitatively the im-

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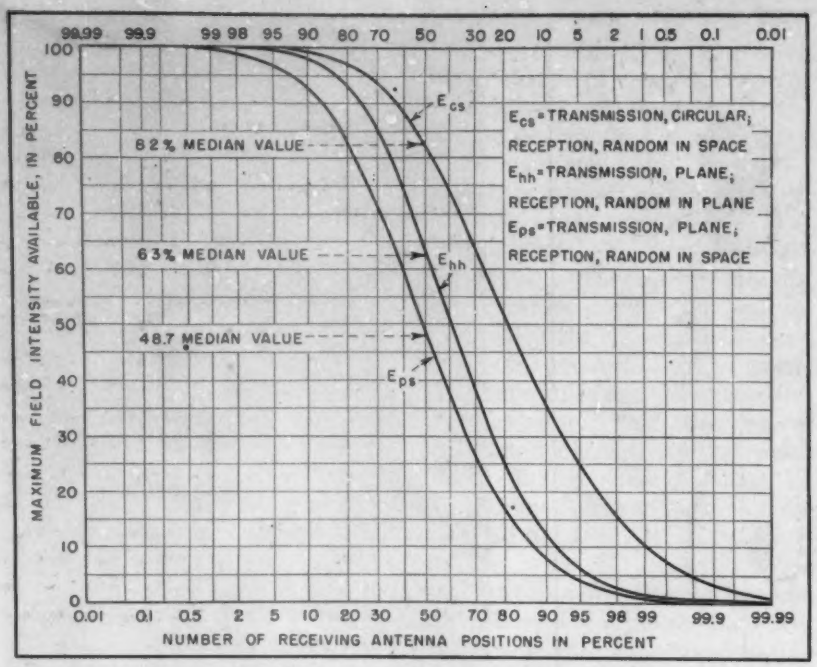
MAXIMUM FIELD INTENSITY AVAILABLE, IN PERCENT
NUMBER OF RECEIVING ANTENNA POSITIONS IN PERCENT
82% MEDIAN VALUE
63% MEDIAN VALUE
48.7 MEDIAN VALUE
E_{cs}
E_{hh}
E_{ps}
E_{cs} = TRANSMISSION, CIRCULAR; RECEPTION, RANDOM IN SPACE
E_{hh} = TRANSMISSION, PLANE; RECEPTION, RANDOM IN PLANE
E_{ps} = TRANSMISSION, PLANE; RECEPTION, RANDOM IN SPACE

FIG. 2—Distribution of field intensity with receiving antennas in random placements

provement of circular polarization over plane polarization, and a research program has been carried on by the Ohio State University Research Foundation in Columbus to develop a high-gain circularly polarized broadcasting antenna.

Theoretical Advantages

One of the principal advantages of circular polarization over plane polarization is that space is more completely filled with a diversely polarized signal. Figure 1 shows that in a plane-polarized field a simple receiving antenna can be placed in only one position for maximum signal pickup and in a whole plane of positions for zero signal pickup, while in a circularly polarized field a simple receiving antenna can be placed in a whole plane of positions for maximum signal pickup and in only one position for zero signal pickup.

It should be emphasized that although the radiated power can be doubled in going from plane to circular polarization the more important consideration is that the polarization changes from a single line or linear dimension to a surface or two-dimension phenomenon. The radiated power from many f-m stations using plane or horizontal polarization is limited to an equivalent 20-kw, 500-foot antenna in accordance with FCC allocation standards. All of these stations have the privilege of improving their service to the public by employing circular polarization and radiating up to an equivalent 40-kw, 500 foot antenna.

If reception patterns are investigated on a theoretical statistical basis by placing a half-wave receiving antenna at random the curves of Fig. 2 result. For a circularly polarized field with receiving antennas placed at random in space the median value is 82 percent. In a plane-polarized field with receiving antennas placed at random in the plane of polarization the median value is 63 percent. If the receiving antennas are placed at random in space when the field is plane polarized the median value is 48.7 percent.

If ratios between the curves of Fig. 2 are expressed in decibels of improvement the two theoretical curves of Fig. 3 result. The median improvement of circular polarization over plane polarization for antennas placed at random in space is 4.6 decibels, while the improvement of circular polarization over plane polarization when the receiving antennas are placed in the plane of polarization is 2.3 decibels. It should be observed that the improvement to 50 percent of the sets will be much more than this value, as indicated by the sharp upward

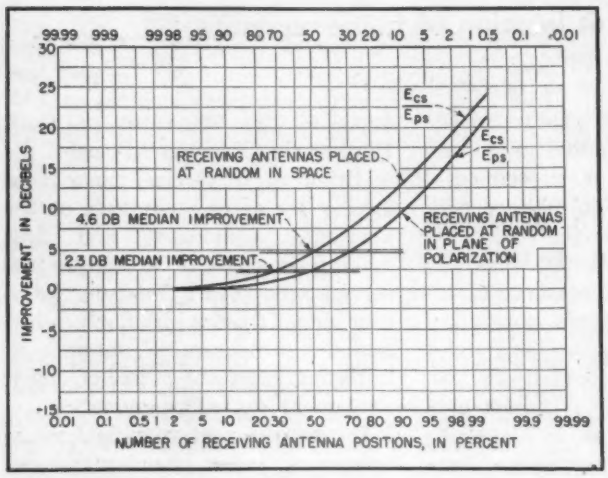
IMPROVEMENT IN DECIBELS
NUMBER OF RECEIVING ANTENNA POSITIONS, IN PERCENT
E_{cs}/E_{ps}
E_{cs}/E_{ps}
RECEIVING ANTENNAS PLACED AT RANDOM IN SPACE
4.6 DB MEDIAN IMPROVEMENT
2.3 DB MEDIAN IMPROVEMENT
RECEIVING ANTENNAS PLACED AT RANDOM IN PLANE OF POLARIZATION

FIG. 3—Theoretical improvement of circular polarization over plane polarization

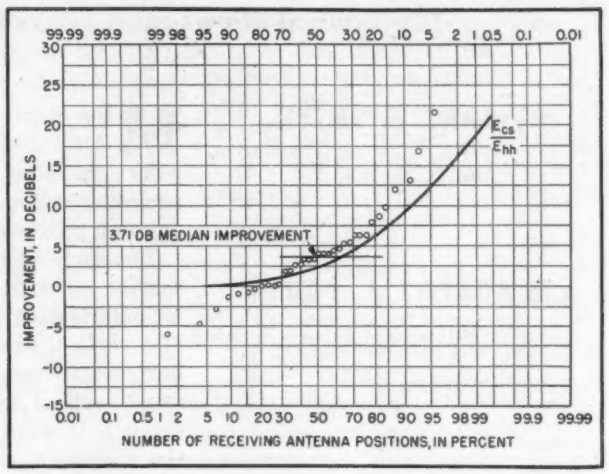

FIG. 4—Improvement of circular over horizontal polarization when receiving antennas are horizontal

curvature toward the right end of these curves.

Field Measurements

To determine quantitatively the improvement of circular polarization over plane polarization as it affects the average home receiver it was assumed that the f-m receiving antenna built into the home receiver must be served. Therefore, 372 carefully controlled field-intensity measurements were made in 36 typical homes throughout the service area of W8XUB.

Measurements in the home were made with a half-wave dipole placed six inches in front and with the center of the dipole level with the top of the home receiver. In other words, an effort was made to reflect into the results the effect of the position of the home receiver as selected by the housewife.

With the test half-wave dipole horizontal, the transmitting antenna was caused to radiate, first horizontal polarization and then circular polarization of equal maximum field intensities. The ratio of these measurements made in 36 homes shows in Fig. 4 that the median improvement is 3.71 decibels. The theoretical curve was also drawn in this figure for comparison purposes. It will be noted that the field measurements data is in fair agreement with the theoretical curve. It is believed that cancellations and reinforcements due to reflections from metalic plumbing and wiring in and around the home cause the measured points to fall below the theoretical curve toward the left end and rise above the theoretical curve toward the right end.

If the receiving antenna is placed at random in space it should be possible to check the theoretical curve of Fig. 3. To accomplish this, measurements of circular polarization transmission with vertical receiving antennas were compared to both vertical and horizontal-polarized transmission with the same vertical receiving antennas. Then a similar set of ratio measurements were made with horizontal receiving antennas. Figure 5 presents 72 such ratio measurements with a median improvement of 4.87 decibels. This is in good agreement with the theoretical median improvement of 4.6 decibels. Again cancellations and reinforcements are believed to be the reason for the statistical data to fall below the theoretical curve at the left and rise above the theoretical curve at the right.

Another case of interest is the improvement that can be expected when the receiving antennas are vertical. A practical application is whip antennas on automobiles and power-cord antennas such as are commonly used on table-model receivers. The 21 statistical measurements for this condition are presented in Fig. 6, which shows a median improvement of 9.25 decibels. The improvement for three points was too great to plot; however, their effect is reflected by shifting the other points to the left.

Summarizing the results indicated by the above field measurements, it is more profitable for a broadcaster to divide the available power between the horizontal and vertical components and employ circular polarization even for serving only horizontal receiving antennas placed in the home. However, such division of total power is not necessary under the Standards of Good Engineering Practice for f-m broadcast stations. Under these standards the broadcaster can expect to more than double the power (3.71 db) in horizontal receiving antennas and increase the power more than eight times (9.25 db) in vertical receiving antennas within the service area.

Antenna Development

The program at the Ohio State Research Foundation embodied basic research on two methods of producing circular polarization. The first employed excitation of a single element geometrically shaped, such as spiral slots or helical antennas, to produce the desired polarization. The second group consisted of horizontal and vertical radiating elements, each fed with the proper proportion of energy to produce equal-magnitude fields and with the proper time-phase difference to produce circular polarization.[4]

In developing the antenna the

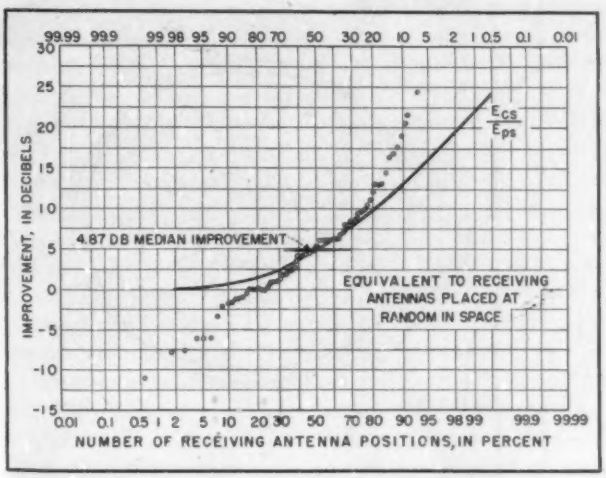
99.99 99.9 99 98 95 90 80 70 50 30 20 10 5 2 1 0.5 0.1 0.01
IMPROVEMENT, IN DECIBELS
4.87 DB MEDIAN IMPROVEMENT
EQUIVALENT TO RECEIVING ANTENNAS PLACED AT RANDOM IN SPACE
NUMBER OF RECEIVING ANTENNA POSITIONS, IN PERCENT

FIG. 5—Improvement of circular over plane polarization with randomly placed receiving antennas

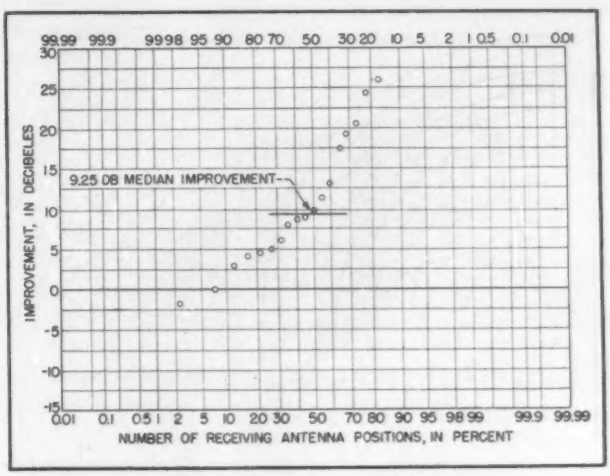
99.99 99.9 99 98 95 90 80 70 50 30 20 10 5 2 1 0.5 0.1 0.01
IMPROVEMENT, IN DECIBELES
9.25 DB MEDIAN IMPROVEMENT
NUMBER OF RECEIVING ANTENNA POSITIONS, IN PERCENT

FIG. 6—Improvement of circular polarization over horizontal with vertical receiving antennas

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problem was attacked theoretically and experimentally by means of model technique.[5] The theoretical work was devoted to slots in cylinders[6] since it appeared early in the development that this type of antenna would probably be used as the radiating element to produce the horizontal polarized component of the circularly polarized antenna.

To produce circular polarization in the horizontal plane it should be remembered that both the horizontal and vertical radiating elements must have a uniform pattern in magnitude and phase. It has been shown[6] that two diametrically opposed axial or longitudinal slots in a cylinder will satisfy the requirement for the horizontal component, as the magnitude was essentially uniform and the phase shift was less than three degrees through the f-m broadcast band for cylinders whose diameters were 16 inches. By making the cylinder a half-wavelength long and feeding the slots at the center, the desired horizontal component can be produced. The vertical component can be obtained by feeding the half-wavelength cylinders as full-wavelength vertical dipoles. The 90-degree time-phase requirement was satisfied by using a phase control as shown in Fig. 7, which also shows the basic elements and how they were developed and combined to produce the circularly polarized experimental antenna as used by station WHKX, and illustrated on the cover of ELECTRONICS for April 1948.

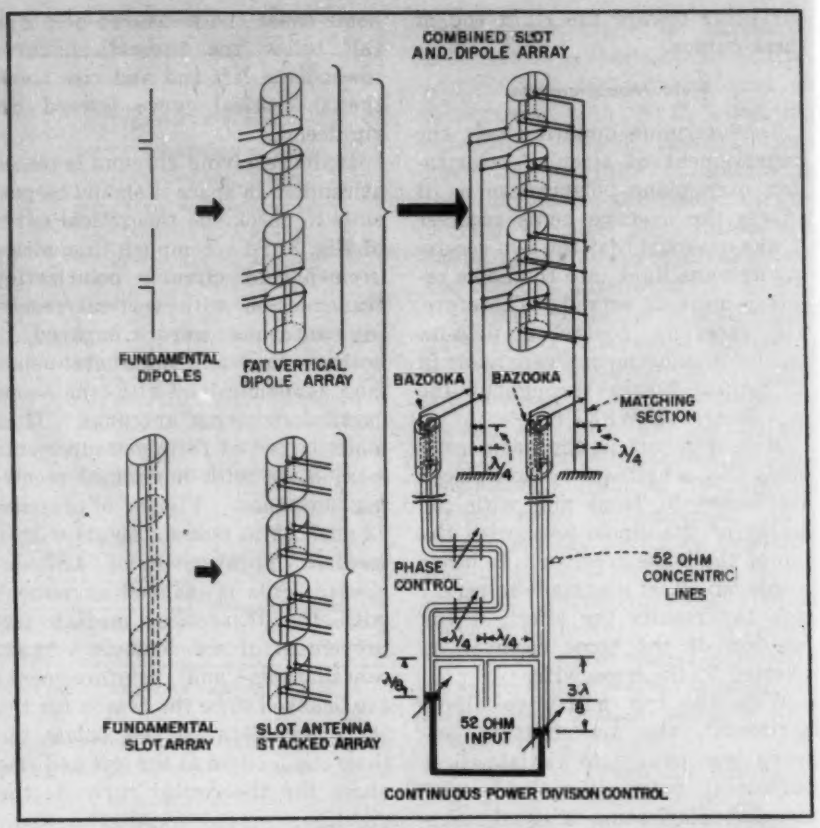

FIG. 7—Development of the circular-polarized antenna from dipoles and a slot array

Experimental data on the slots showed them to have vertical patterns which were similar to the vertical fat dipole and indicated that the units or full-wavelengths bays could be stacked suitably for high gain. Vertical patterns at 100 mc for both elements are shown for half-wave cylinders 16 inches in diameter, in Fig. 8. The horizontal-plane patterns for the two elements are quite uniform, as shown in Fig. 9. With this basic information a model for a circularly polarized antenna was constructed and tested. Pattern tests proved the antenna to be circularly polarized in the horizontal plane and that the units could be stacked for high

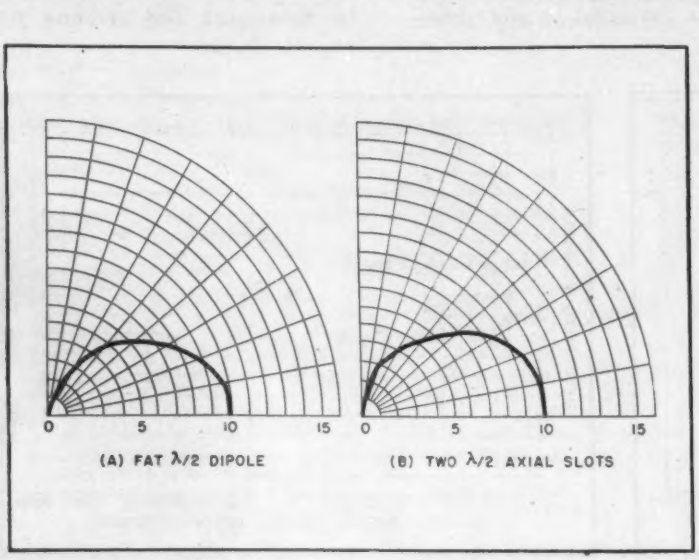

FIG. 8—Vertical field patterns for both vertical and horizontal-polarized elements at 100 mc, using 16-in. diameter cylinder

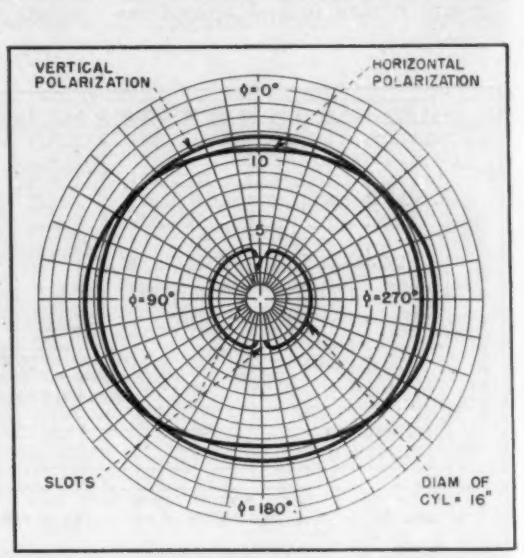

FIG. 9—Vertical and horizontal-polarization components of horizontal-plane pattern at 100 mc

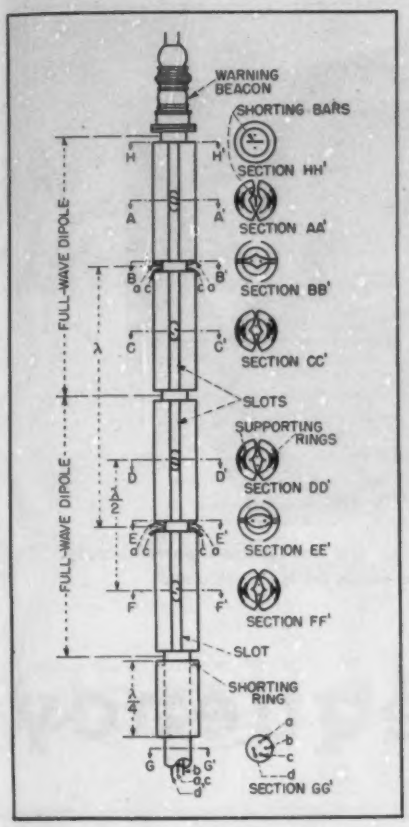

FIG. 10—Construction and feed details

gain. As a result of these studies the full-scale antenna was fabricated and installed for experimental operation.

The Antenna

One unit, or bay, of the antenna consists of two half-wavelength cylindrical sections with two diametrically opposed axial (longitudinal) slots cut in each section as shown in Fig. 10. For the vertical radiating element, the two cylindrical sections are fed at the center of a vertical full-wavelength fat dipole. Since the units are one wavelength long, the feeding problem is simple when the units are stacked in a vertical collinear array, to obtain a high-gain vertical pattern. The horizontally polarized component is obtained by feeding the axial slots, cut in each section of the cylinder, in phase with equal amplitudes of current so the circular pattern in the horizontal plane is obtained.

Feeding the antenna can be accomplished with a multiwire balanced transmission line as shown in Fig. 7 and 10, or a coaxial-line feed system can be employed throughout. The full-scale model employs a balanced four-wire line. The copper-clad steel conductors are stretched from the top to the bottom of the supporting mast and on the inside of it. One pair of conductors is used to feed the vertical radiating elements and the other pair the horizontal radiating elements. The correct phase relationship for the two slots in each cylinder is obtained by properly crossing the connectors from the transmission lines to the slots as shown in Fig. 10. Since the feed points from one cylinder to the next cylinder are a half wavelength apart, altering the crossed connectors keeps the units in phase so they can be stacked. The feed points for the dipoles are one wavelength apart and can thus be fed in phase to produce a simple collinear array of stacked elements.

Each section of the galvanized-iron cylinder shell is fastened to a standard 10-inch steel mast with metal castings to support the shell to the mast. This is possible because the support point is at zero potential, being an odd quarter-wavelength away from the vertical-polarization feed points and equidistant between the horizontal feed points. This keeps the entire antenna free of insulators. A quarter-wavelength skirt is placed at the bottom of the antenna to minimize currents on the supporting structure. Bazookas are used to transform from balanced to unbalanced transmission lines as shown in Fig. 7.

With independent phase and power control it is easy to adjust for true circular polarization. The condition of polarization is determined at WHKX by a half-wave sampling dipole mounted level with the center of the circular-polarization antenna on a wooden pole at a distance of about 100 feet. This dipole can be rotated by a rope control to any position in a plane at right angles to the direction of propagation. The r-f meter at the center of the dipole can be observed by using a telescope mounted in the transmitter building.

The gain of the antenna is a function of the number of units or bays and may be determined by the conventional method used in computing the gain of collinear arrays.

Commercial Antennas

For commercial antennas it may be more desirable to use a concentric transmission line harness-type of feed throughout. By first resonating and then controlling the resistance magnitude at the various antenna-element feed points the standing waves on the feeder lines can be reduced to a minimum. The commercial broadcast antennas can be fabricated in this fashion. All openings in the cylinders will be covered with plastic to minimize effects from weather conditions. It will then be practical to bulk heat the antenna structure if icing is expected to be severe enough to require it. A ladder can be mounted on the cylinders without affecting the radiation pattern, thus making it easy to service the flasher beacon at the top of the antenna.

Acknowledgments

The authors wish to acknowledge the following assistance: H. K. Carpenter, executive vice president of United Broadcasting Co. for his sympathetic interest; George Sinclair of the University of Toronto for his invaluable contributions in the circular-polarization antenna development program; Robert Jacques, Research Supervisor of the Ohio State University Research Foundation Antenna Laboratory for his cooperation; A. O. Austin and Robert Indorf for directing the fabrication and construction of the full-scale developmental antenna.

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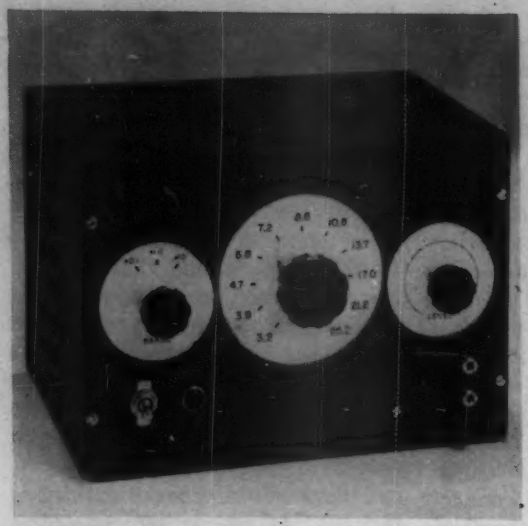
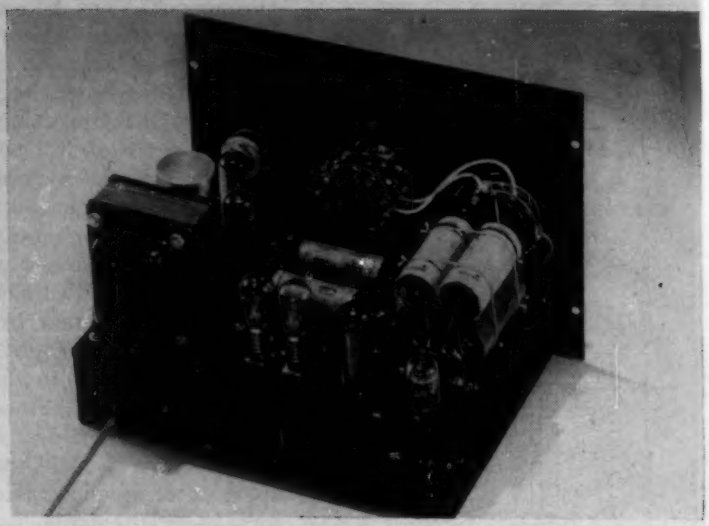


The low frequency oscillator showing range switch, step frequency selector, and level (gain) control



Top chassis view of the oscillator and conventional power supply. The two 6-watt lamps are in the feedback circuit

Low-Frequency

Stable oscillations from 0.3 to 252 cps are obtained in three ranges. The ganged variable-resistance tuning elements give small stepped increments of frequency. Lamps are used for nonlinear negative feedback

By JOSEPH F. KEITHLEY
Keithley Instruments
Cleveland, Ohio

OSCILLATORS in the frequency region below 20 cps have numerous laboratory uses, particularly in the study of vibration problems and in the design and testing of amplifiers which use a large amount of negative feedback.

The two major obstacles to be overcome in designing a satisfactory low-frequency oscillator are the large sizes of the components and the time required for transients to disappear. Because of the low impedance and low Q of inductors in this region, the frequency-controlling elements are almost always resistances and capacitances; and with the comparatively low resistances of wire-wound resistors and potentiometers it is difficult to hold capacitors to a reasonable size. In oscillators with only vacuum tube nonlinearity controlling the amplitude, circuit changes in adjusting the frequency and selecting the range of frequencies cause transients lasting as long as 15 cycles, which is 30 seconds at 0.5 cps, making additional amplitude stabilization desirable.[1]

Beat-frequency oscillators, with the fixed frequency at 1,000 cps, have operated satisfactorily in the low-frequency regions. Time, however, is required to be certain that the zero-beat error is negligible; and a good quality filter is required to eliminate the unwanted modulation components from the desired signal.

The circuit diagram shown in Fig. 1 is fundamentally that of a resistance-capacitance oscillator with nonlinear feedback for stabilizing the amplitude.[2] The frequency-controlling network is of the series R-C, parallel R-C type, and was chosen because only two variable elements are required. Resistance changes are used to control the frequency over a range of 10 to 1, and the decades are selected by varying the associated capacitance. Resistors R_1 and R_2 are the variable parameters, and C_1 through C_6 are the fixed. They give an overall range from 0.32 cps to 252 cps. Negative feedback is controlled by R_3, R_4 and R_5, with R_4 and R_5 the nonlinear resistors. Tube V_1 is a voltage amplifier, and V_2 drives the frequency-controlling and negative-feedback networks.

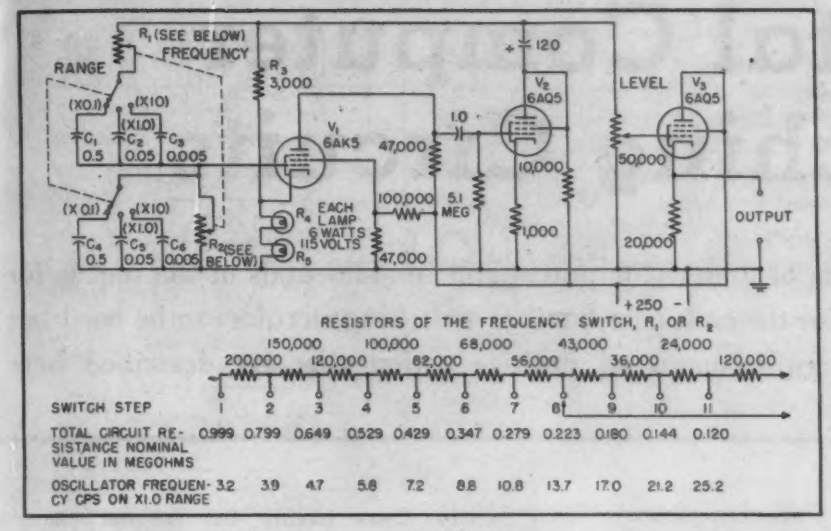


FIG. 1—Circuit diagram of the low-frequency oscillator. The stepped variable frequency control detail indicated

Oscillator

Cathode-follower V_3 isolates the output. The power supply is conventional.

In the circuit of Fig. 1, $f = 1/2\pi RC$, where f is the frequency of oscillation; R is the resistance of R_1 or R_2, assuming them equal; and C is the capacitance of the associated capacitors, assuming they also are equal. Resistors R_1 and R_2 are controlled by a two-section, eleven-point frequency selector switch. At each range setting, if a factor of 10 in frequency is desired for a complete sweep of the frequency switch, along with a proportional increase in frequency with each step of the switch, then the ratio of increase is $10^{1/11}$, or approximately 1.23 per step. This relation, in turn, means a division of the previous value of R_1 or R_2 by 1.23 for each increasing step of the frequency switch. One megohm was a convenient value for the maximum of R_1 and R_2. Using this, the incremental resistances were computed, and the nearest RMA-value resistor was selected. One half-watt resistor was used for each incremental resistance; these mount conveniently on the frequency switch, and result in a neat and compact control. The switch and resistor combination gives a stable, variable resistor with high resistance, so that only a 0.5 μf capacitance is required for the 0.3 cps to 2.5 cps range. The schematic diagram of R_1 and R_2 is shown at the bottom of Fig. 1.

Capacitors C_2 and C_3, C_5 and C_6 were selected and trimmed to fit the decade relationship with C_1 and C_4, respectively. The capacitors C_1 and C_4 were chosen within 5 percent of each other.

Thermal Elements

The choice of the thermal characteristics of the nonlinear resistors in the feedback circuit is a compromise between two requirements. It is desirable that the thermal time constant be as short as possible, so that transients caused by changing the frequency or the range will be as short as possible. Yet there should be no appreciable change in resistance during a cycle of oscillation at the lowest frequency, or waveform distortion will result. Two 115-volt 6-watt candelabra-base lamps connected in series were found experimentally to give acceptable waveform at 0.5 cps, damp transients quickly, and have satisfactory electrical characteristics.

The chief limitation of the oscillator is that the frequency cannot be varied continuously. In most work encountered, the steps have been adequately close. Additional increments, however, can be obtained by using a selector switch with more steps, using ranges of 3 and 30 in addition to 1, 10, and 100, or by connecting auxiliary decade capacitors across the frequency-controlling capacitors.

As noted previously, the lower frequency limit of oscillation is determined by the thermal elements in the feedback circuit. The upper limit, with R_1 and R_2 maxima of 1 megohm, is reached when the tube, switch, and wiring capacitances become appreciable compared with those of the oscillating circuit. A convenient limit for the present oscillator is 252 cps.

Accuracy

The finished oscillator has been calibrated carefully, and the range capacitors adjusted so that the error in frequency is less than 2 percent of any given setting. The use of tubular paper capacitors and composition resistors in the frequency-controlling network, however, means that errors as great as 4 to 6 percent can be expected. This error can be reduced by the use of more stable elements; or a spot calibration can be made whenever a critical situation is encountered.

The low-frequency oscillator has given good service for several months, and seems to be a generally satisfactory instrument. Through the techniques of a switch-controlled variable high resistance and nonlinear negative feedback, a simple, stable, easy-to-use oscillator has been built in a frequency region once noted for its difficulties.

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Digital Computer Switching Circuits

Basic operational requirements of digital computers and fundamentals of the means for obtaining them are set forth. For the most part familiar switching circuits can be used but they must meet the special requirements of positive action that are described here

By C. H. PAGE

Chief, Electronic Computers Section
National Bureau of Standards
Department of Commerce
Washington, D. C.

AUTOMATICALLY-SEQUENCED digital computers are machines that have no intelligence, yet carry out, without intervention, lengthy routines of mathematical calculation. An understanding of general design considerations requires a survey of the procedures followed by a human computer using desk calculator.

A human computer does more than arithmetic; he not only carries out the elementary processes of addition, subtraction, multiplication, and division, but he also decides what numbers to add, multiply, etc., and what to do with his results. These results of his arithmetic are only stepping stones to his final goal, just as the numbers upon which he performs his arithmetic were previous stepping stones. Some problems require millions of arithmetic operations to arrive at a relatively small set of numbers representing the final answer.

If we reduce the human computer to an automaton having only the ability to read, write, and do arithmetic, we need to give him a very detailed set of working instructions. These instructions include original numerical data from which he works, and an explicit program of operations to be performed. He must be told, for example, to read numbers in two specified places, add them, and write the result in a specified place. He must then be told where to find his next instruction, unless all instructions are serially listed and no variations in their order are to be made. Explicit instructions as to where to write partial results and when and where to refer back to them for further use comprise a sort of automatic memory. The sheets of paper, numbered for identification, form a storage for numbers; his whole program is stored on paper before he starts to work.

Even the power of decision can be mechanized. If a human computer is supposed to compute one intermediate result to a specified degree of accuracy by a method of successive approximations, he must continue until further steps make insignificant changes. He is therefore instructed to keep repeating the procedure until a tentative answer, taken to ten places, equals the previous tentative answer, and then to proceed with the main program.

We see that our automaton must be given instructions, or orders, incorporating the following information: (1) where to find operands; that is, the two numbers to be combined by addition, multiplication, subtraction, or division, (2) which arithmetic operation to perform, (3) where to write the result, either in a specified place for future reference or on his final answer sheet, and (4) where to find his next set of similar instructions.

An electronic computer operates on a similar routine. Machines being designed and built will perform this cycle of operations in a millisecond or less, working with numbers having ten decimal places. Such speed means that these machines will make it practical to solve problems requiring so many millions of arithmetic operations as not to be considered at present. Directing such a machine is a major administrative problem. As Dr. von Neumann of the Institute for Advanced Study expressed it, "Programming a problem for such a machine is equivalent to writing a detailed set of instructions for twenty automatons with desk calculators sufficient to keep them busy for two years, working a forty-hour week." These automatons have no ability to think for themselves!

Leaving the mathematical and administrative problems to others, we can proceed to the basic electronic problems. We must first have (A) an electronic alphabet for writing numbers and orders, (B) a medium on which to write, (C) means of writing and reading, and (D) means for interpreting the written word. These words may be numerical, as 3721499825, or coded orders, as A0173Q75B6. When a number-word (number) is read, it must be translated into what the machine recognizes as numerical form. An order-word (order) must be interpreted by being converted to a set of voltages, to operate switches.

Reading a word consists in part of transmitting it to the organ which is to interpret and be affected by it. Thus numbers are transmitted from storage to arithmetic unit, or vice versa, and orders are sent from storage to the central control organ, or dispatcher. In ad-

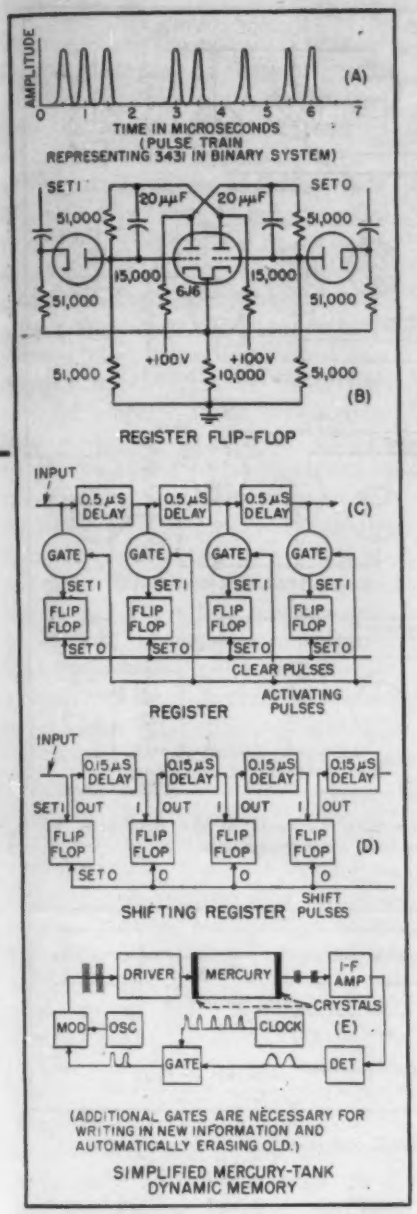

FIG. 1—Pulses are stored statically in flip-flops, dynamically in delay lines

dition, both kinds of words are transmitted to storage from the input as needed, and final answers or desired partial results are transmitted to the machine output.

An order must not only tell the central control which numbers to dispatch to the arithmetic unit from storage, but must also tell central control which arithmetic operation is to be performed and where the result is to be sent.

In addition to the central control organ, there must be various local control stations. The arithmetic unit itself, for example, is primarily a traffic unit such that the arrival of two numbers causes the transmission of a third number. Whether this third number is the sum, difference, product, or quotient of the other two depends upon the dispatching system of the arithmetic unit. Separate arithmetic units can be built for the four cases, but it is also feasible to make a universal arithmetic unit which will perform any one of the four processes upon request of the central control. Hence the central control must not only dispatch number-words and orders, but must also interpret orders and actuate circuit changes.

Transmission and Representation

A NUMBER, say 43712, can be read and transmitted in two fundamentally different ways. If one transmission channel is used for each column, we can simultaneously transmit a 2 along the first channel, a 1 along the next, 7 along the next, etc. This simultaneous transmission of the digits of each position along their appropriate channels is a PARALLEL operation. Its characteristic feature is that it distinguishes between digits by a spatial relation, transmitting all digits at the same time.

Conversely, we could transmit all digits over a common channel, at successive times, in the order 2, 1, 7, 3, 4. The separate digits would be distinguished by their time of arrival on a common line. This is a SERIAL process, digits being distinguished by a temporal relation.

If ten pulses, made recognizable from each other by modulation, are available, any number can be transmitted either serially, over one line, or in parallel, over many lines, from one organ to another. We will consider only serial operation because it is more illustrative of traffic (switching) dispatching problems, as well as because it is the system employed in the machines that will first be constructed.

ORDERS to various parts of the machine must also be capable of transmission, hence they can be expressed conveniently as numbers in some arbitrary code. Thus numbers and orders are represented in the same way, being strings of digits. We know which is which when we put them into the machine, so that if our programmer dispatches only orders to central points and numbers to arithmetic points, it will not matter that the machine by itself cannot distinguish orders from numbers. In fact, this is a convenience, because by considering an order as a number we can modify an order by operating on it with the arithmetic unit.

REPRESENTING the ten digits by pulses of different amplitude would reduce machine reliability, making results depend upon tube constants and supply voltages. It is better to have only two amplitudes to distinguish. If these two amplitudes represent digits 0 and 1, we must find a way of representing numbers in terms of these two digits. In decimal notation, the number 352 means

$$2 \times 10^0 + 5 \times 10^1 + 3 \times 10^2 = 2 + 50 + 300$$

Each successive digit position to the left represents the coefficient of the next higher power of 10. We therefore need digits only to 9; a coefficient of 10 in any place is equivalent to a coefficient of unity in the next place. If we drop the use of 10 as our base, and use 2 instead, we write a number such as 37 in the following binary manner, 100101, meaning

$$1 \times 2^0 + 0 \times 2^1 + 1 \times 2^2 + 0 \times 2^3 + 0 \times 2^4 + 1 \times 2^5 = 1 + 4 + 32 = 37$$

We pay for the simplicity of having only two different digits by needing approximately three times as many columns to write a number in the binary system as in the decimal system.

To represent 0 and 1 and the corresponding pulse trains, we choose a basic pulse repetition rate of 2 mc, and synchronize all parts of the machine so that successive pulses (representing 0 or 1) occur at these half-microsecond intervals. If all trains of pulses are locked to this reprate (repetition rate), we can use the presence of a pulse to represent 1, and the absence of a pulse to represent 0. Thus the six-microsecond pulse train shown graphically in Fig. 1A represents the binary word 110101100111 (read from right to left) which has the (decimal) value 3431. Voltage and tube parameters need only be held within the tolerance range to

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keep the pulses within their amplitude range of reliable operation.

Now that we have a scheme for representing numbers as pulse trains, we are ready to analyze problems of storing numbers.

STORAGE — Typical machines operate with numbers of ten significant figures in the decimal system, so will require roughly 35 binary places. A 35 binary place number at 2-mc reprate will be represented by a pulse train having a duration of 17.5 microseconds. It is impractical to put information into a machine or to print results at such a rate, over 50,000 words per second. We need a speed changer, or device for storing the many words being written into it at one speed, and capable of being read at some other speed, either faster or slower. One scheme is magnetic recording of the pulse trains on either wire or tape. Magnetic pulses cannot be packed more closely than about 200 per inch if they are not to overlap and become incapable of resolution. The reprate of reading and writing magnetically for a given packing is proportional to the speed at which the wire is transported. Hence we can magnetically record pulse trains leisurely and run them into the machine rapidly or conversely, can record fast signals on a fast wire, and later read the wire at a speed which an electric typewriter can reliably be expected to follow.

Inside the machine we need two types of memory, one that stores a train of pulses statically and another that stores the high reprate trains of pulses.

STATIC REGISTER — The first of these, the static register, is needed, among other places, in the arithmetic unit, to set up central voltages in accordance with the 0's and 1's of a number. Basically a static register is a flip-flop such as that of Fig. 1B which has two stable states. High and low plate voltages can be taken to represent the storage of a 1 or a 0.

In a practical flip-flop, grid capacitors are used to speed transition from one state to the other. Minimum transition time depends upon mutual conductance of the tubes. A more rapid flip-flop than the one shown can be made by using such tubes as the 6AK5, connected either as pentodes or triodes. Provision is also made for setting the flip-flop in either state by applying a negative pulse to the appropriate tube. The diodes are isolation buffers to disconnect the pulse sources when pulses are not being applied. This not only reduces loading on the transfer pulse from one tube to the other, but also prevents this pulse from being transmitted to other flip-flops via the input circuit.

Tying the two input leads together provides a binary counter. The plate-grid coupling capacitances provide enough memory (time lag) for the flip-flop to remember in which state it was prior to the application of a pulse applied to both tubes. As a result, an input pulse changes the state of the flip-flop and provides a scale-of-two, or binary counter. Cascaded binary counters have many applications. For binary counter purposes, the grid input arrangements can be omitted and a positive pulse applied to the common cathode lead.

By using 35 flip-flops, one for each binary column, we can statically store a 35 place binary number. Writing a number into a register consists of setting its flip-flops in accordance with the succession of 0's and 1's in the binary number. Reading the register consists of causing it to generate the pulse train corresponding to its array of 0's and 1's.

FEEDING REGISTER — There are

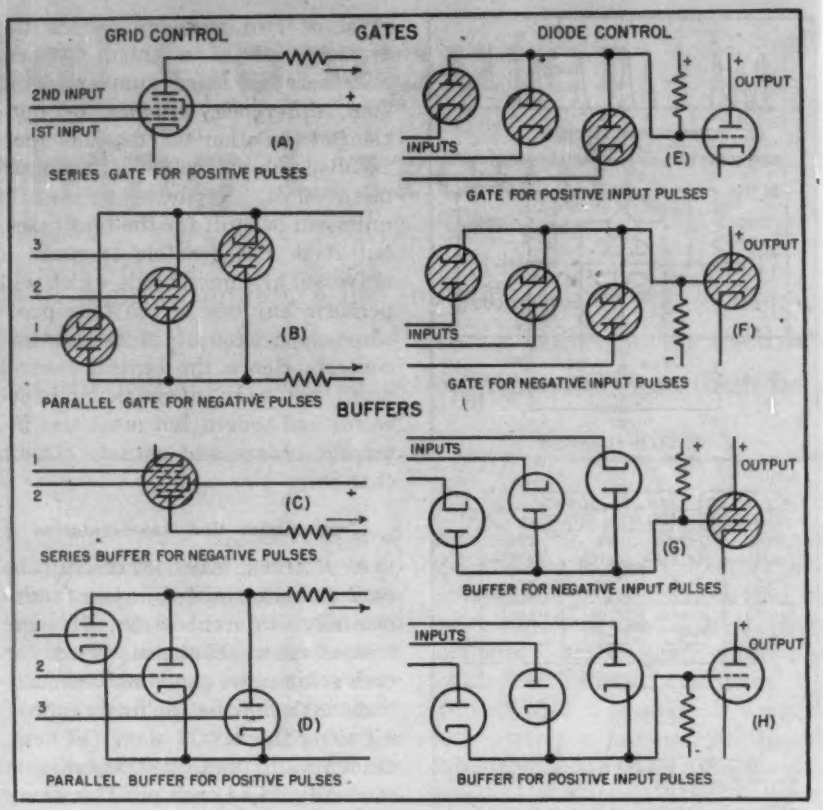

FIG. 2—Gates and buffers constitute the operating elements of the arithmetic units. Germanium diodes may be used for compactness

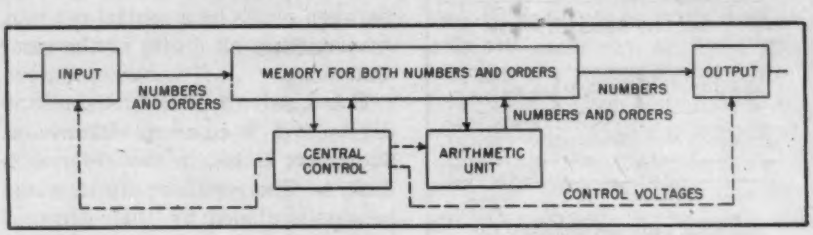

FIG. 3—Basic functional components of digital computer, and their interrelation

two ways of converting a serial train of pulses into the parallel form for storage in the static register. The pulses can either be fed into the register from the end or set up in parallel alongside it.

The latter scheme is indicated in Fig. 1C; the train of pulses is fed into a delay line of 0.5 μs sections, so that just as the last pulse appears at the input the previous pulses appear at the various junctions. The delay line thus momentarily converts the serial pattern of voltage peaks versus time into a spatial pattern of voltage versus position; voltage appears at the junctions corresponding to the positions of the binary 1's in the number represented, no voltage appears at the positions corresponding to 0's. When this space pattern is obtained, all the gates are opened by an activating pulse, and the 1's are entered into the register via the set 1 input leads. The register can be cleared by applying a pulse to the set 0 inputs.

If the plate outputs of the flip-flops are connected to successive junctions of a duplicate delay line, clearing the register (by simultaneously setting all flip-flops to 0) will introduce pulses into the line at the 1 positions; these pulses will come out of the delay line as the desired train.

The other scheme for sending a train into a static register is somewhat similar to the operation of some desk computing machines that have only 10 keys, 0 through 9. Pushing 3 enters 0003 on the dials, then pushing 5 shifts the 3 along as the 5 is entered, showing 0035, etc. This sequential to parallel conversion can be accomplished by the shifting register of Fig. 1D.

The set 0 lines are all connected to a shift pulse bus. A shift pulse then clears all flip-flops, and any registering 1 generate output pulses. These pulses arrive at the set 1 leads of the next flip-flops, transferring the 1's one place to the right. Clearing a flip-flop registering 0 generates no pulse, so leaves the next flip-flop cleared to 0. Hence every time a shift pulse is sent in, the contents of the register shift to the right. If the shift pulses come at a 2-mc reprate, evenly interspersed between the 2-mc signal pulses sent into the left-hand flip-flop, every time the register is shifted it will find the next digit of the train in the left-hand flip-flop and 35 shifts will result in a static storage of the 35 pulses in the train. We now stop the shifting and have the number stored.

Reading the register (regenerating the train of pulses) is simple. The output of the right-hand flip-flop is connected to a transmission bus and 35 shifts are made, sending the successive 1's and 0's onto the line, and leaving the register cleared to all 0's, assuming that no signal is coming in from the left.

The static registers described above require two tubes per binary digit, or 70 tubes per word stored, so are uneconomical for the main storage. (A general purpose computer needs storage facilities for at least 1,000 words). However the static register is useful in the arithmetic unit for intermediate storage between two organs with different speeds, such as internal parts of the machine and the magnetic wire. One word at a time can be written at any speed, and then read at any other, permitting synchronizing input data pulses with the 2-mc clock, which would be impossible to do by trying to run the wire at an exact speed.

The other internal high-speed memory, or scratch paper, of the machine can either hold pulse trains as a static array, or remember them dynamically; that is, in the form of pulse trains available for retransmission on demand. Only the latter choice will be discussed here.

DYNAMIC MEMORY—The simplest way of achieving dynamic memory is to feed pulses into a delay line whose output is connected back to the input to keep the pulses circulating. An amplifier and pulse regenerator are needed at the delay line output to compensate losses. Distorted pulses from the line are used to control a gate feeding fresh pulses from the master pulser, or clock, back into the line. Such a gating combination in the recirculation system is referred to as a pulse reshaper.

The losses of an electric delay line are too great. Each word to be stored requires 17.5 μs of line to hold it; this implies a total of 17.5 milliseconds of electrical delay line, whether in one or several segments. To transmit the individual 0.2 μs pulses without excessive distortion requires a bandwidth of 10 mc. Even with the optimistic figure of 6 db per μs attenuation in lines having this bandwidth, attenuation would be 105,000 db, requiring 7,000 tubes such as the 6AK5 having a gain of 15 db per stage. This is excessive.

A practical way to simplify dynamic storage is to store pulses acoustically rather than electrically. We can convert the 0.2 μs pulses into 0.2 μs packets of h-f using a carrier frequency of 20 or 30 mc. These h-f pulses can then be used to drive a quartz crystal which in turn generates waves in a mercury column. A receiving crystal at the far end senses these waves giving a signal that is amplified and rectified to regenerate the pulses. Attenuation in mercury is approximately 0.06 db per μs at a carrier frequency of 30 mc, or one percent of that for the electrical line. The pair of crystal transducers used with the line introduces a loss of about 50 db.

If one long delay line is used, coupling losses would be negligible, but a single delay line of 17.5 milliseconds would require on the average a waiting time of 9 milliseconds before the desired word would be available. This is too long. A practical compromise between equipment and speed is to subdivide the memory into lines, or tanks, of 20 word capacity, each having a delay of 350 μs. Thus 50 lines are needed, involving 50 pairs of transducers having 2,500 db attenuation. Adding the attenuation of 1,050 db in the mercury, we have a total of 3,550 db attenuation (to be compared with the 105,000 db of electrical lines) and requiring only about 250 amplifier tubes. A typical recirculating tank circuit is shown in Fig. 1E.

We now have conceptually a source of input signals, a receiver for output signals, an arithmetic unit, static registers and dynamic memory tanks. Signals must be dispatched from one to another of

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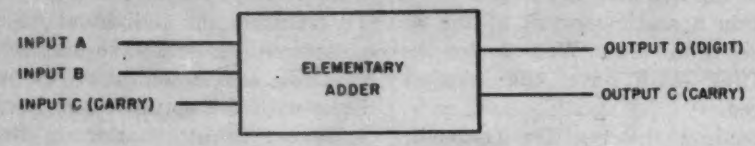
Table I—Operation of an Elementary Adder

Terminals of Elementary Adder



List of Binary Input-Output Combinations

In A.....	0	0	0	0	1	1	1	1
In B.....	0	0	1	1	0	0	1	1
In C.....	0	1	0	1	0	1	0	1
Out D.....	0	1	1	0	1	0	0	1
Out C.....	0	0	0	1	0	1	1	1

Rules of Arithmetic

Binary operations	Logical concepts
(1) A single input 1 generates a 1 and no carry	(1) (A AND B) or (A AND C,) or (B AND C) generates a carry
(2) Two input 1's generate a carry but no output	(2) A or B or C generates an output digit unless one of the above AND combinations occurs, which operates a gate to prevent the transmission of the digit
(3) Three input 1's generate both and output and a carry	(3) A AND B AND C generates both digit and carry

Functions of Elementary Adder

Transmit a digit if A OR B OR C and not A AND B, A AND C, nor B AND C, or if A AND B AND C
Generate a carry if A AND B, A AND C, or B AND C

these organs. In general, any organ may be called upon to send signals to any other. The simplest way of doing this is to connect all tank inputs to a common point through switches (electronic gates) and to connect the arithmetic unit output to this point. Then opening the proper gate will allow the signal to proceed to the chosen tank, and to no other. Conversely, if several sources are to be capable of sending to several receivers, all sources can be connected in parallel to a common transmission bus, and the receivers connected to this bus through gates. Then by opening a receiver gate, and instructing the proper source to transmit, the desired result should follow. In practice, this would not work, for with many sources in parallel, each source would be loaded by the parallel combination of the output impedances of all the others. We need, between each source and the common bus, a buffer which allows only one way traffic, so that a signal can come from a source through the buffer to the bus, but the other sources cannot load the bus. The use of a buffer between an oscillator and a modulated r-f amplifier is well known. In our case of passing pulses of only one polarity, we do not need a triode or pentode buffer, but can use a diode. This diode is normally biased with back voltage so that it presents a high impedance to the common bus. A pulse on the bus increases the back voltage on the diodes and is protected. A pulse from a source, however, reverses the polarity on that one diode and goes through with small loss. The advantage of such buffers is that germanium diodes can be used, greatly reducing shunt capacitance.

With gates and buffers we can perform circuit switching, or spatial selection for traffic control. If we stored our 1,000 words in 1,000 one-word tanks, there would be an exorbitant number of switches with their attendant losses and control problems. We could compromise on 50 tanks holding 20 words each. We can choose any one of these 50 tanks by spatial switching and any one of the 20 words in a tank by temporal selection. The temporal selection requires no switches aside from the timing gate.

The timing circuit can be operated by dividing the master clock rate. The 2-mc reprate drives a counter which counts up to 35 and then throws a flip-flop, giving an output which is on for 35 pulses, or one word time, and off for the next. By feeding these rectangular waves of word duration into a scale-of-20 counter, we can devise a circuit which will give an output (to control a gate) for the duration of any desired one of the twenty words.

Arithmetic Circuits

To understand how to combine gates and buffers to make a circuit that will do arithmetic, it is convenient to interpret gates and buffers in terms of their logical behavior.

A GATE is essentially a device having two inputs and one output. Either input can be considered as the signal, and the other as the control. Obtaining output from a gate is dependent upon stimulating both inputs; that is, it requires stimulation of one input AND the other input. Logically the gate detects the AND concept, one thing AND another.

BUFFERS, on the other hand, that feed two or more signals to a common point give an output signal if any one of the sources is excited; that is, if one OR another input of the row of buffers is stimulated. Hence two buffers connecting two inputs to one output constitute the logical concept of OR, one signal OR another.

Typical gate and buffer circuits using tubes are shown in Fig. 2. The series gate of Fig. 2A has both grids normally biased beyond cutoff; both must be driven above cutoff to produce an output. The parallel gate of Fig. 2B has all tubes normally conducting. If the load resistor is large compared to the conducting resistance of a single tube, the common plate voltage will remain low unless all tubes are cut off by signals.

The series and parallel buffers of Fig. 2C and 2D represent inverse operating conditions on the corresponding gate circuits. The nor-

mal-abnormal conduction states are interchanged, and the circuits are stimulated by pulses of sign opposite to those required by the corresponding gates. A signal on any input produces a change in the output.

The diode circuits of Fig. 2 are all parallel circuits. Gates, requiring the AND or multiple coincidence, have all their diodes normally conducting, while buffers have all their diodes normally nonconducting. Diodes are generally of the germanium type.

Adder Is Basic Element

To add two digits, the basic operation of arithmetic, we need two inputs and one output. If the sum of the two digits is greater than 9 in the decimal system, or greater than 1 in the binary system, a carry will be produced to add in the next digit position. Hence we need three inputs, one for each digit in the given position, plus one for the possible carry from the previous position. We also need two outputs, one for the output digit, and one for the carry. Thus each digit position requires a device as shown in Table I. Operating characteristics of this elementary adder can be deduced from the laws of arithmetic. The desired outputs for the eight possible input combinations of 0 and 1 on the three inputs are listed in the table.

There are two types of adders: parallel and serial.

A PARALLEL ADDER is made of 35 elementary adders, one for each digit position. Various digits are set up in a static register, as previously discussed, and the steady register output voltages representing 0's and 1's activate static elementary adders. The carry output lead of each place can be permanently connected to the carry input lead of the next, requiring one type of elementary adder to satisfy the rules of arithmetic. Alternatively the sum and carry digits can be formed statically in each place, and the carrier transmitted to their neighboring adders an instant later. Part of the difference in the circuitry is involved with the fact that a carry may generate a carry, as in adding 7774 to 2226. Propagation of the carry down the line can be handled in various ways.

THE SERIAL ADDER uses a single complicated elementary adder for successive digit places in sequence. Pulse trains are not set up in static form, but are fed in dynamically, the two numbers arriving simultaneously. If an output 1 pulse is generated, it is transmitted immediately as one digit of the sum. If a carry pulse is generated, it is delayed 0.5 μs and returned to the carry input, arriving there coincident with the input digits of the next place.

An elementary adder can be made of gates and buffers. Rules of arithmetic shown by the list of input digit combinations are stated in Table I. The preventing operation in case (2) implies a negative gate, or logical AND NOT, which is easy to devise from diodes by using several bias levels. With this terminology, the functions of an elementary adder can be described logically as at the bottom of the table. The complicated combinations of AND and OR are straightforward logically and electronically, but lead to a practical circuit employing (in one design) nine pentodes and 36 diodes! Some of these elements are incorporated to reshape pulses, and several diodes are used as limiters and d-c level restorers.

Any adder can be considered as a problem in traffic control where the signals (numbers) that are put in control the transmission of pulses throughout the adder. This local control is one step more complicated than the central control, or traffic dispatch between organs. In the central control problem, control voltages set up the paths to be taken by signal pulses. In the local control, pulse paths, and times (clock beats) at which pulses occur are set by the signals themselves, so that there is no longer a clear-cut distinction between signal and control pulses.

MULTIPLICATION is a more complex problem. Ordinary longhand multiplication consists essentially of adding the multiplicand (574) as many times as the right-hand digit of the multiplier (31) shifting columns, adding on the multiplicand as many times as the next digit, etc., as in the example:

```
 574          574
  31          31
-----   =    -----
 574          574
1722          574
-----         574
17794         574
             -----
             17794
```

Because in the binary system, only 1's and 0's occur, we have for the partial products either the multiplicand itself, or zero.

```
Decimal          Binary
  23             10111
   5             101
-----   =        -----
 115             10111
                 00000
                10111
                -------
                1110011
```

This allows us to use a shifting register (previously described) together with a basic adder, to perform multiplication. We do or do not add in the multiplicand according to whether the right-hand digit of the multiplier is 1 or 0, shift the number in the register, and repeat. Thus a basic arithmetic unit consisting of registers, which can be shifted when desired, gates and buffers, can either add or multiply according to whether it gets a simple signal to add, or whether it gets also a signal to shift and repeat. Other modifications permit subtraction and division. Which operation is to be performed is controlled by signals from central control, usually quasi-static voltages to keep certain gates open until the operation is completed.

Before examining means for converting pulse trains representing arbitrarily coded orders into gate control voltages, let us glance at the overall organization of the computer.

The input portion of the machine sends all its words, both numbers and orders, to the high speed memory storage. From storage, orders go to the central control, logically through a decoder, but this decoder is the main part of the central control and so is not usually considered separately. Central control must dispatch operating instructions to all machine units, including the input, for it must tell the input when there is room in the memory for more data and orders

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to continue the problem. The general scheme is shown in Fig. 3. The only feature of the diagram that is unnecessary is the transmission of orders (not control voltages) to and from the arithmetic unit. This is a useful way of pyramiding the hierarchy of control to achieve versatility of operation. Because orders themselves are coded to appear as numbers, orders can be modified by performing arithmetic upon them. This feature simplifies programming the mathematical problem in terms of dispatching orders, but need not concern the electronic circuit designer.

We have mentioned that orders are coded in numerical form. Suppose for example that eight different orders are desired; that is, eight different lines are to be energized. Any eight things can be represented in code form by the binary numbers 0 to 7; that is, 000, 001, 010, 011, 100, 101, 110, 111. These are the eight combinations of three places, each having either of two values. Electrically, we can have three wires, each of which may have voltage applied. If orders are pulse trains they can be converted to the static three wire combination by setting up a static register of three flip-flops. We then have three wires, any one or more of which may be hot, representing eight different possibilities, and we wish to excite any one of eight leads in accordance with these choices. In general, we have N wires of two possible states each (hot or cold) giving 2^N combinations, and wish to excite only one of 2^N outputs. In practice, instead of using N wires from N flip-flops, having some hot and some cold, it is better to bring two wires from each flip-flop, one from each side. We then have N pairs of wires, each of which has only one side hot. All input pairs are thus excited one way or the other, avoiding complications of zero-voltage input signals.

The simplest case of a decoder is where $N = 2$, so that there are two input pairs and four output leads. The circuit of Fig. 4A shows this case. The horizontal and vertical lines are connected through diodes, so that the diodes in any column form a gate, or AND circuit. If upper and lower lines of the top pair are excited positively, output from the left-hand lead is excited, and so on for the four possible combinations of input.

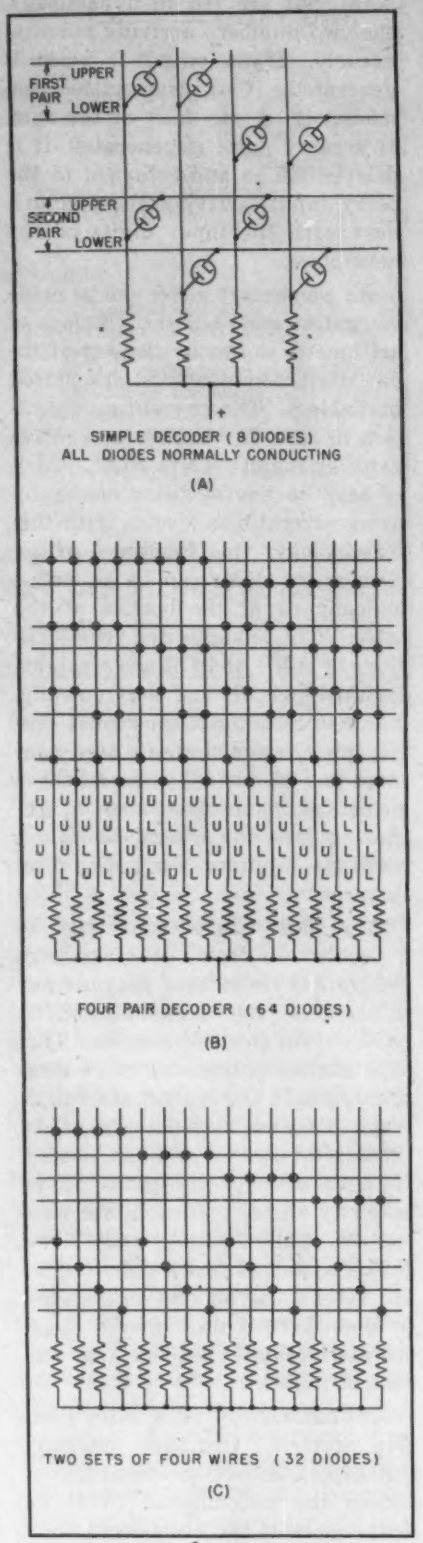

FIG. 4—Switching circuits use unidirectional conductance of diodes

For larger decoders, it will be convenient to indicate the presence of a diode connection between two lines by a circle at the crossover. There are no direct connections. Figure 4B shows a simple decoder for four input pairs, yielding 16 possible output excitations. Combinations of upper and lower pair excitations that result in excitation of each of the 16 lines are indicated on the figure.

This direct check of the possible combinations can be called a one-stage decoder. Fewer diodes are required if we decode in two stages, namely, by mixing two pairs as in Fig. 4A to get one line out of four, and doing the same with the other two pairs to get one line out of another set of four. We then have two sets of four lines each, in which only one line of each set is excited. These two sets can be fed into the circuit of Fig. 4C. Thus in using Fig. 4B, each output line requires a quadruple coincidence for excitation, and 64 diodes are needed. By using two circuits of Fig. 4A and one of Fig. 4C, making successive simple coincidences, we need $8 + 8 + 32 = 48$ decoders, or a saving of 25 percent.

Multistage decoding exhibits even greater savings as N increases. For $N = 8$, allowing selection of any one of 256 memory tanks by virtue of the $2^8 = 256$ different gates that may be opened by an 8-pulse signal, a three-stage decoding requires only 608 diodes as against 2,048 for single-stage decoding.

Traffic Handling Systems

Having seen how a coded order can be converted to the selection of a gate opening voltage, it is of interest to consider briefly the general traffic handling plan. The mathematician prepares his instructions to the machine in terms of numerical data, coded orders to select which basic operation the arithmetic unit is to perform, for sequencing the machine or for expressing the routine to be followed. In general two kinds of words are put into the machine memory: numbers and orders.

Assume that the memory is capable of storing 1,000 words and, for

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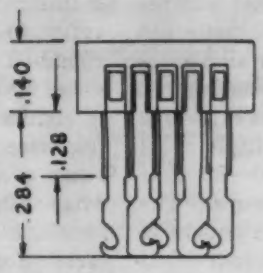

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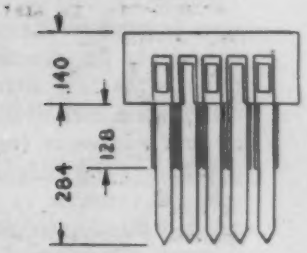

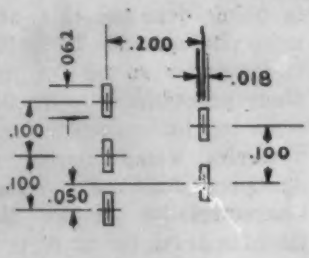

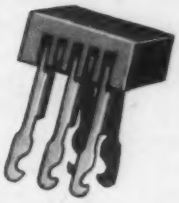

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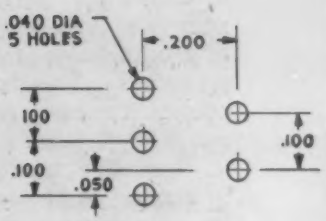

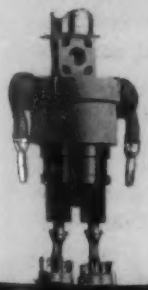

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simplicity, that the two kinds of words are of equal duration, or number of pulse positions. These 1,000 words occupy definite positions in two dimensional space-time. Hence we can consider their positions as pigeonholes numbered from 1 to 1,000 and call for transmission of a word to or from any pigeonhole. The simplest way of entering the input data is to take the first thousand words from a magnetic wire and store them sequentially in the thousand cells. This can be done by using a counter to measure off a word, and cause unity to be added to the address to which the next word is to be sent.

High speed reading of the memory can also be done sequentially by giving the address 1 as the instruction for the cell to be read and by having a built in arrangement for automatically adding unity to the address of the cell to be read. It will then automatically read cell 2 as soon as it has finished with cell 1 and is ready to read again.

A procedure that may be more flexible for repeating subsequences and setting up branch operations (choice of next order depending upon present results) and also more convenient in practical programming is the four address code. In this system each order is composed of four addresses (or memory cell locations): the address of the first operand (number to be arithmetically operated upon), the address of the second operand, the code for the operation to be performed, and the address of the next order to be read after completion of the present instructions. This system is more efficient if memory reference is slow compared to other operations; that is, if waiting time for a word to be reached in the sequential reading of a dynamic memory is relatively large because it allows the essentially simultaneous look-up of both operands.

A variation of the four address system is the use of a fifth address in the words on the input wire, to designate the cell into which that word is to be stored. The fifth address is automatically deleted as the word is entered into the machine.

In electronic digital computers, the tubes, for example, are called upon to develop a pulse of usable level, or not called upon at all. Variations between tubes, aging, or tolerances of resistors do not affect accuracy, until they become so extreme that the signal falls out of usable range. A ten to twenty per cent variation of signal strength has no effort on a series of pulses. Ideally a computing machine works perfectly or not at all. Actually, as tubes deteriorate, there is a threshold at which operation may be erratic. By setting a limit checking circuit for a safe level margin, this otherwise possible operation can be put in the class with complete breakdown.

Errors can occur due to noise generating a false pulse at an allowed pulse time when the word transmitted has a zero in that position. This noise pulse may be indistinguishable from a proper pulse. Occurrence of errors due to such random causes can be guarded against by one of several checking schemes.

One of the most elaborate checking schemes that has been proposed is to check the arithmetic and the transmission. The arithmetic can be checked in a fashion similar to the ancient system of casting out 9's, where each number is expressed as its excess over a multiple of 9; that is, it has a value of 0—8. This is done by adding sideways. The 9's excess of a sum of numbers is equal to the sum of their individual excesses, (expressed as an excess if larger than 9). The 9's excess of the product of two numbers equals the (excess of the) product of their excesses. A simple auxiliary addition or multiplication on the excesses has often been used for checking arithmetic. For example, multiplying 371 by 24 gives 8904. The 9's excess of 371 is found by adding the digits $3 + 7 + 1 = 11$, $1 + 1 = 2$. Similarly, the 9's excess of 24 is 6. The product of these two excesses is 12, having itself an excess of 3, which agrees with the excess of 8904, $8 + 4 = 12$, $1 + 2 = 3$. A corresponding procedure of casting out $(2^r - 1)$ can be set up for binary computation, and a small auxiliary arithmetic unit operated simultaneously with the main unit.

This type of checking lends itself to verifying correct transmission of a number. The excess count of a number can be stored with it in the memory for performing the parallel arithmetic check. It can be used as a transmission check by taking the excess count of a number received by the arithmetic unit and comparing it with the received check count. Very peculiar transmission errors are required to make the new count of an incorrectly transmitted number agree with either its original count or an incorrectly transmitted count. This type of checking is based on arithmetic.

Checking the address selection exercised by central control can be done by storing with each word its address. When the word and accompanying address is read, the read address is checked against the called-for address. This checks both the spatial and temporal phases of word selection in the machine.

Electronic design of machines is fast progressing to the point where they will be more perfect than the mathematics set up for them. I refer to such varied factors as round-off error, inevitably introduced by working to a fixed number of significant figures. If a machine performs 1,000 arithmetic operations a second for days on end, what relationship does the final answer have to the original hypotheses? Some mathematical research is being done on this point. A more vital question is the design of mathematics suited for machines. Many procedures use machines for replacing human computers, using numerical computational schemes developed for the human brain. Characteristics of an electronic machine are different from those of a human brain, and it is reasonable to suppose that computational procedures can be devised which, although unsuited for hand computing, are well adapted to machine routines. Such procedures have been developed for a few special problems.

The writer thanks the Raytheon Manufacturing Company and the Eckert-Mauchly Computer Corporation for supplying some of the circuit details shown in the figures.

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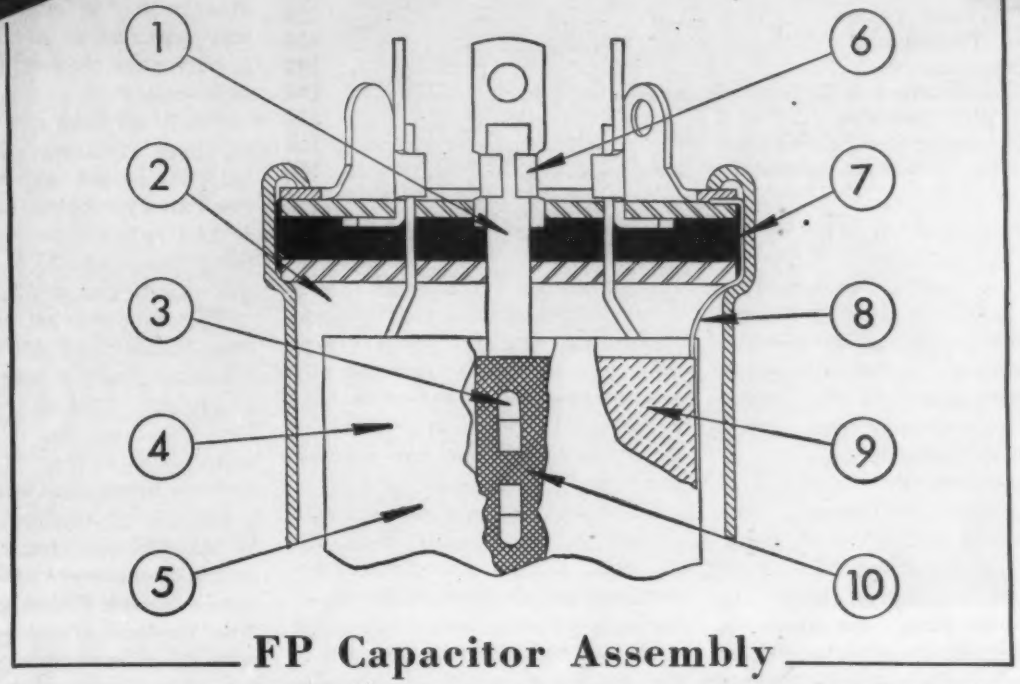

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TUBES AT WORK

Including INDUSTRIAL CONTROL

Edited by VIN ZELUFF

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Mobile Television Receivers

TELEVISION receivers mounted on three jeeps operated by an automobile club made it possible for several additional thousands of people to see the telecasts of the national political conventions from station WCAU-TV, Philadelphia.

The receivers were mounted so that they faced the sidewalk when the jeep was parked on the right-hand side of the street. Thus each jeep could be parked along the highway enabling spectators to watch the television picture from the sidewalk without producing a traffic hazard.

Table model television sets were used, standard Philco model 1001 receivers with 10-inch direct-view screens. As the picture shows, each television set was mounted on a special rack at the right rear of each jeep, and a 12-foot aluminum antenna was also mounted on the side of each jeep. The antenna comes in 6-foot sections, and two sections were used.

For driving along highways with bridges or low-hanging trees, the top mast section and dipole were detached and strapped to the top of the jeep. A single half-wave dipole without a reflector was fastened to the top mast section. This was connected to the receiver by a 70-ohm coaxial line to minimize ignition interference from passing automobiles.

Philco ten-inch table model television receiver mounted on a jeep for the convenience of roadside viewers

Such an installation is useful for observing television reception in various locations. Measurements of field strength may be taken by checking agc voltage and multipath may be observed by watching the picture. The jeeps had standard JAN ignition suppression and in the absence of bad standing waves it was possible to obtain a steady picture when the jeep was traveling at 30 mph.

Power for each set was supplied by three 120-ampere-hour storage batteries in the back of each jeep. One battery supplied heater voltage at 14.4 amperes to all tubes. For the purpose, the 5V4 damper tube was replaced by a 6W4.

The other two batteries supplied two Mallory VP-555 Vibrapacks whose total output was 340 volts d-c at 140 ma. Cold-cathode 0Z4 rectifiers were used and filament power was applied at least 30 seconds before the Vibrapacks were energized.

Initially planned by the staff of WCAU-TV, the idea was executed by Philco engineers under the direction of Joseph Fisher, project engineer, Research Division, Philco Corporation. One engineer from Philco Service accompanied each jeep, with the regular uniformed drivers of the Keystone Automobile Club. The jeeps are normally used for emergency calls and are equipped with mobile radiotelephone, and now have mobile television.

Taxi Tele

Taxicab operation of a television receiver is reported by G. W. Fyler of Motorola. The receiver used was a Motorola VT-71 in which the 12 and 25-volt tubes were changed to 6-volt tubes of similar characteristics. A Mallory Vibrapack was added for plate supply. This was mounted away from the receiver to prevent hum components in the picture. Filters designed for the television frequencies to be used were also added.

Modifications to the receiver included series-connected VR tubes for plate supply regulation and adjusting the time constant of the agc circuit to about 0.01 second. This permitted fast circuit action in standing waves but not so fast as to lose too many low-frequency components, including the vertical sync

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pulse. Adequate heater voltage was found important to stabilize sync action.

To cover both the high and the low channels, an all-band antenna was shortened and modified at the center as a compromise between good performance at the proper length and ease of mobility of the vehicle.

Ignition suppressors and special generator filtering were found desirable but no special shielding was added to the receiver circuits. It was found to be important to have low set and car noise during minimum signals in the standing wave pattern.

The high-channel signals seemed to have more standing waves and ghosts. In severe standing waves the agc was able to follow signals on the low channels better because the standing waves occur about three times as far apart. Video and audio signals seemed to have different standing wave patterns.

Signals from the high-band channels were stable in open flat country but tend to have somewhat deeper shadows behind hills as expected. Standing waves were found to be greatest near large metal structures such as a bridge but were often perfectly stable under the bridge. Strangely, slight ghosts appeared in a few areas in flat open country without overhead wires or other objects that cause reflection.

Industrial Tube Tester

THE EFFICIENCY of gas or mercury-filled industrial tubes such as thyratrons and phanotrons is tested by the circuit shown in Fig. 1.

In most cases, gas or mercury vapor tubes are used as high-current, low-voltage devices. For that reason, this General Electric tube tester is designed to test the ability of the tube with high current passing through it. The passage of current may readily be seen by noting the familiar blue glow.

Tube efficiency can be determined by measuring the voltage drop from anode to cathode when rated peak anode current is passed. With the TT-1 tube tester, the rated peak, anode current is carried by the tube under test for a half-cycle shot once per second, thus preventing the cathode of the tube from warming up due to the passage of current. The lowering of the voltage drop due to passage of current can easily be checked by allowing the tube to conduct during short portions of each cycle for a few minutes and noting the change in the dial setting required to light the indicating neon tube. This is the reason for making the test reading on the first five conducting cycle positions. A voltage drop of 25 volts is usually considered the maximum limit for good tubes at rated peak anode current.

An anode-to-cathode voltage of 110 volts is placed across the tube for one-half cycle of a 60-cycle source by means of a contactor which is opened and closed by an electronic circuit when the test button is pushed. Various peak currents may be put through a tube by changing the load resistor to various selector settings. When current passes the tube under test, a voltage drop appears across the tube which lights the indicating neon light if the voltage drop exceeds the rated value. The zero calibration is set for a series of tests to compensate for the slight change in the tube characteristics in the electronic calibrating circuit.

In testing ability of the tube to pass current, other defects of the tube are automatically tested. If a tube is leaky or gassy, has an open filament or low emission, it will immediately show up as having poor ability by a high voltage drop.

Mercury vapor pressure inside of tubes nearly doubles for every 10 C rise in temperature. Too low a mercury pressure causes a high-voltage drop from anode to cathode and therefore speeds up the positive ions in the region between the anod and cathode, resulting in bombardment of the delicate cathode coating. A higher mercury pressure lowers the tube's voltage drop but also lowers the ability of the tube to withstand inverse voltage. For these reasons, mercury tubes have a minimum and maximum temperature limit, usually from 40 to 80 C.

Temperature is measured at the point where condensation takes place, usually at the bottom of the tube. A test of the ability of the tube as given by the TT-1 tube tester is made at the lower temperature limit so that tests will be under the highest voltage-drop condition. However, in low ambient temperatures a longer period than the cathode heating time is required in order to get the condensed mercury temperature of the tube to this lower temperature limit.

For this reason, and also because it is necessary for the mercury to be properly distributed (all condensed in the bottom of the tube), a heating time longer than the normal cathode heating time is called for in the instructions for use of this tester. A condensed mercury temperature of 40 C is usually taken as the temperature for measuring the ability of the cathode.

Gas-filled tubes differ from mercury-filled tubes in that the gas pressure does not vary excessively in normal temperature conditions of

(Continued on p 136)

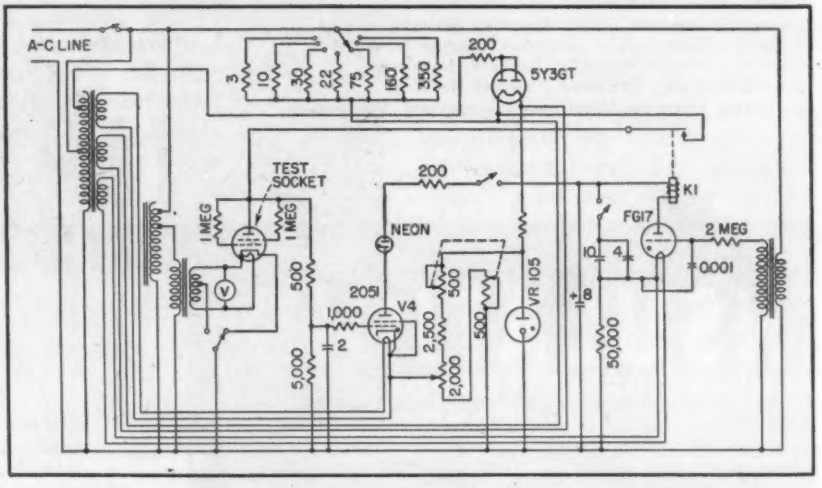

FIG. 1—Complete circuit of tube tester for phanotrons and thyratrons

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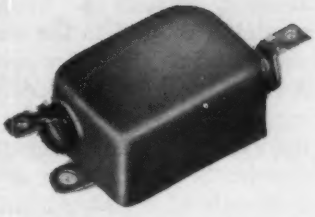
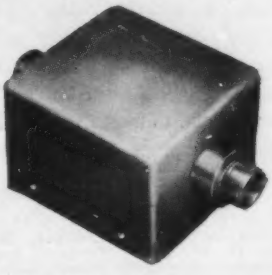


2.5 amp Filtron for 50 V. D.C. operation size 1¾" X 1¼" X ⅞"



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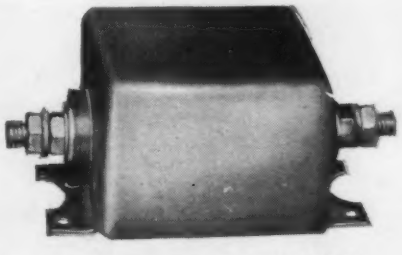

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THE ELECTRON ART

Edited by FRANK ROCKETT

Detection of Microwaves 124
Plotting Electron Paths 124
Electronic Circuit Has Logarithmic Response 166
Survey of New Techniques 178

Detection of Microwaves

ABSORPTION OF MICROWAVES by gases has been studied to determine such physical constants as molecular dipole moments.[1] In these investigations thermal and acoustic effects have also been observed.[2] Using the expansion produced in gases by their absorption of microwave energy it has been possible to detect as little as 10 milliwatts with relatively simple apparatus. The absorption phenomena can also be used, at low gas pressure, to stabilize the frequency of microwave oscillators as effectively as oscillators of lower frequency are stabilized by quartz crystals.[3]

Microwave Wattmeter

Figure 1 shows a wattmeter. The resonant gas-tight metal cavity is filled with a highly absorbing gas such as ammonia or one of the Freons. The cavity communicates with the U-tube in which is a light liquid that does not react with the gas. When a transmitter generating 10 watts is coupled to the resonator the liquid is deflected about 12 inches in a second; equally rapid response is obtained when the power is cut off.

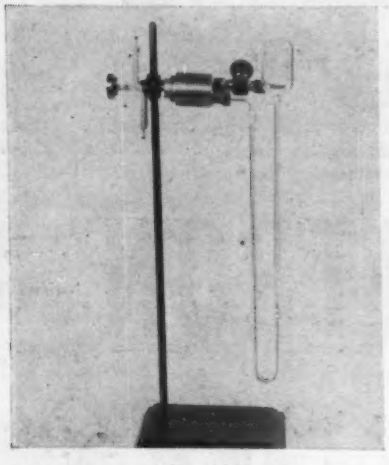


FIG. 1—Wattmeter utilizes expansion of gases produced when they absorb microwaves

This type of wattmeter can be used with 1.25-cm and 3.2-cm transmitters delivering either continuous or pulsed power. The action is a consequence of the conversion by resonant molecular absorption of the microwave energy, followed by collisions of the excited molecules thereby converting their internal energy into an increased gas pressure.

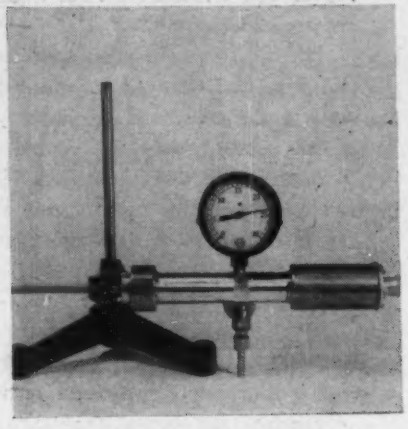


FIG. 2—Gas-filled cavity is acoustically resonant to modulation, electrically resonant to carrier frequency

Resonant Absorber

The conversion of microwave energy into gas pressure can be used directly as a detector of modulated microwaves. If a balloon, filled with an absorbing gas, is placed in the throat of a horn excited by a microwave transmitter, the modulation will be heard for some distance as the gas in the balloon expands and contracts in proportion to the instantaneous energy of the wave. Such an arrangement constitutes a true *wireless* receiver.

The technique can be used in a sensitive detector having square-law response. A gas-filled cavity is arranged that is acoustically resonant at the modulation frequency and electromagnetically resonant at the carrier frequency, as shown in Fig. 2. A study of the optimum wave configurations for excitation of the cavity indicated that the microwave energy should be confined to only half of the cavity. A cutoff guide can be inserted at the midsection to confine the electromagnetic waves without disturbing the acoustic waves. A Rochelle-salt crystal is coupled to the aluminum disc that seals the end of the cavity. A conventional audio amplifier and vacuum-tube voltmeter complete the experimental equipment. It is sufficiently sensitive to detect 10 milliwatts of modulated uhf.

The same technique could be used by a football coach to communicate with a quarterback. The coach would use a highly directional voice-modulated microwave transmitter. The quarterback would have a helmet equipped with a gas-filled ear piece.

(1) W. D. Hershberger, The Absorption of Microwaves by Gases, *Jour. Appl. Phys.*, p 495, June 1946; p 814, Oct. 1946.
(2) W. D. Hershberger, E. T. Bush, and G. W. Leck, Thermal and Acoustic Effects Attending Absorption of Microwaves by Gases, *RCA Review*, p 422, Sept. 1946, on which the foregoing article is based.
(3) W. D. Hershberger and L. E. Norton, Frequency Stabilization with Microwave Spectral Lines, *RCA Review*, p 38, March 1948.

Plotting Electron Paths

By PAUL J. SELGIN

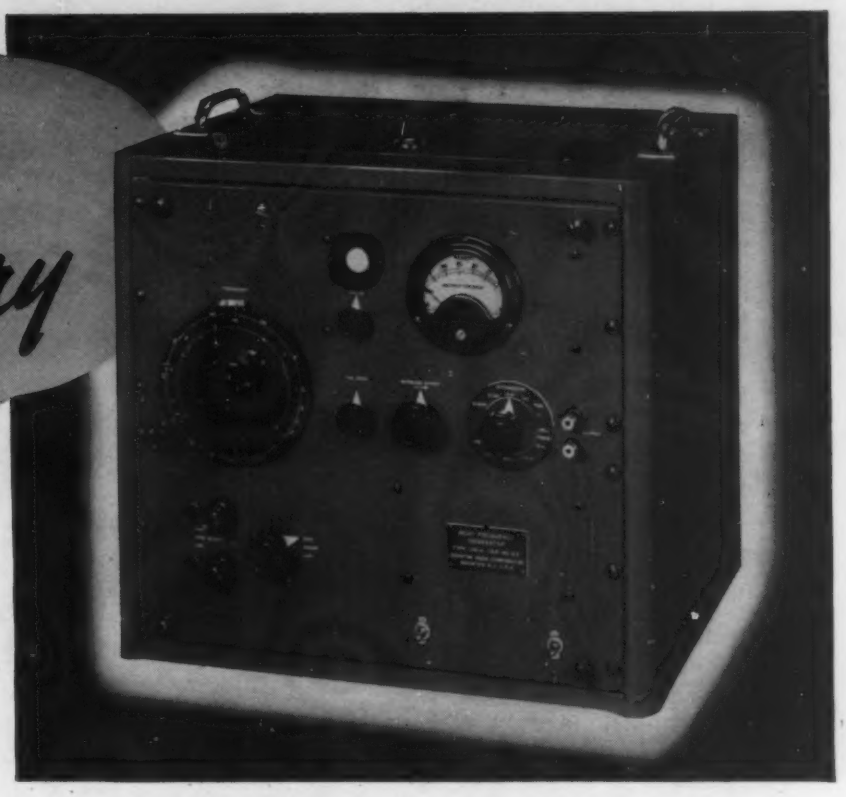
Ordnance Development Division
National Bureau of Standards
Washington, D. C.

TRAJECTORY OF AN ELECTRON is frequently determined graphically. The method described here uses a universal set of curves developed on the assumption that the electron trajectory between equipotentials is an arc of a parabola. The curves are used in conjunction with a map of the electric field in which the electron moves, and requires knowledge of the initial position and velocity of the electron in that field.

Development of Method

While the greatest difficulty in most engineering problems lies in

For the Laboratory



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Low range: 20 to 30,000 cycles.
High range: 30 kc to 5 megacycles.

FREQUENCY CALIBRATION: Accuracy ±2 cycles up to 100 cycles, ±2% above 100 cycles.

STABILITY: About 5 cycles drift below 1000 cycles. On low range, drift becomes negligible percentage with increasing frequency. On high range, drift is 3% or less.

ADJUSTMENT: High and low ranges have individual zero beat adjustments. Low range may be checked against power line frequency with front panel 1 inch cathode ray tube.

OUTPUT POWER AND IMPEDANCES: Rated power output: One watt, available over the low frequency range from output impedances of 20, 50, 200, 500, 1000 ohms, and over both high and low frequency ranges from an output impedance of 1000 ohms.

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VOLTMETER ACCURACY: ±3% of full scale reading.

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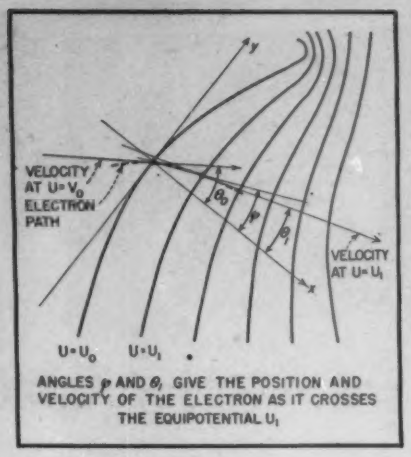
y
VELOCITY AT U=V0 ELECTRON PATH
VELOCITY AT U=U1
x
U=U0
U=U1
ANGLES φ AND θ1 GIVE THE POSITION AND VELOCITY OF THE ELECTRON AS IT CROSSES THE EQUIPOTENTIAL U1

FIG. 1—Notation for general problem

reducing the problem to a mathematical statement, in the study of electron paths the equations of motion, though readily obtained, are difficult to solve. In most design problems the electron does not reach relativistic velocities, so that its mass can be considered constant. Usually there is negligible magnetic field, and, for beams of low density, the region is also free of electrostatic charges. Although this latter assumption will introduce an error, the error is slight and can be taken into account geometrically.[1] These simplifications lead to the equation of motion

$$(d/dt)\ \boldsymbol{V} = (e/m)\text{grad}\ U \qquad (1)$$

where $\boldsymbol{V}$ is a vector representing the electron's velocity, U is a vector representing field potential, whose value in a charge-free region can be obtained by calculation or by an experimental technique such as the electrolytic tank[2]; m represents the mass, and e the charge of an electron. Because the values are expressed in MKS units, there are no numerical constants.

Equation 1 cannot readily be integrated because of the difficulty of expressing U in analytical form for usual configurations. On the other hand, because U is usually available in the form of equipotential contours, the partial derivatives of $\boldsymbol{V}$ along Cartesian coordinates X, Y, and Z can be determined, and can be considered constant within a small region of the field.

The basis of this graphical method is to assume that the potential gradient is constant between equipotentials, and to compute the trajectory through this region. Then another short span is similarly treated, and so on. To make it practicable to repeat the process, a simple graphical method is developed.

Universal Curves

To systematize the construction, an analytical expression for the motion of an electron is obtained and a universal plot is made from which individual problems can be solved by projection.

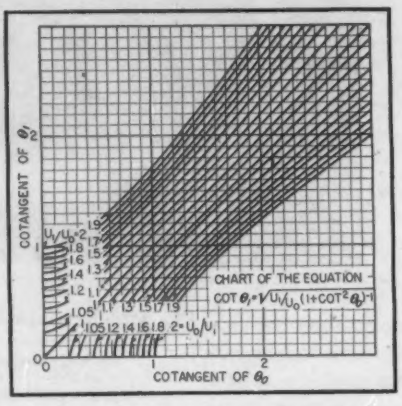

FIG. 2—Chart of universal equation

Due to the initial assumptions, Eq. 1 becomes

$$A_X = (e/m)\,(U_1 - U_0)/X_1 \qquad (2)$$
$$A_Y = 0$$

having taken the X axis perpendicular to the equipotential contour U_0 at the point where the electron intersects it (the origin for this particular phase of the solution), A_X is the acceleration in the X direction, U_0 is the potential contour at which the velocity of the electron is given, and U_1 is the contour at which it is to be found; X_1 is the distance between contours (Fig. 1).

With the above orientation of coordinates, there is no acceleration in the Y direction. For fields of usual symmetry, there will be no acceleration in the Z direction, and it will be assumed that there is no initial component of velocity in the Z direction. Integrating Eq. 2 gives

$$V_X = V_{X0} + \frac{e}{m}\,\frac{U_1 - U_0}{X_1}\,t \qquad (3)$$
$$V_Y = V_{Y0}$$

in which V_{X0} and V_{Y0} are the given initial components of velocity. Integrating Eq. 3 gives the coordinates of position of the electron

$$X_1 = V_{X0}\,t + \frac{1}{2}\,\frac{e}{m}\,\frac{U_1 - U_0}{X_1}\,t^2 \qquad (4)$$
$$Y_1 = V_{Y0}\,t$$

At time t_1 the electron crosses contour U_1 at position X_1, Y_1. From the above equations it is seen that, under the assumed conditions, the trajectory between contours is a segment of a parabola.

Because the time of flight is usually not of interest, it need not be found. The magnitude of the final velocity can be determined from

$$V^2 = 2\,(e/m)\,U \qquad (5)$$

in which U is the total potential difference through which the electron has fallen. From the geometry of the problem as shown in Fig. 1

$$\begin{aligned} Y_1 &= V_{Y0}\,t \\ (Y_1/X_1) &= \tan\phi \\ (V_{Y1}/V_{X1}) &= \tan\theta_1 \\ (V_{Y0}/V_{X0}) &= \tan\theta_0 \end{aligned} \qquad (6)$$

where ϕ determines the point where the electron intersects U_1, θ_1 indicates the path of intersection, and θ_0 is the angle of intersection of U_0. Using these relations, the pairs of parametric equations (Eq. 4) can be reduced to

$$\cot\phi = 0.5\,(\cot\theta_0 + \cot\theta_1) \qquad (7)$$
$$\cot\theta_1 = \pm\left\{(U_0/U_1)\,(1 + \cot^2\theta_0) - 1\right\}^{1/2}$$

Only the second of these relations need be considered, and only the positive sign need be chosen for it. The negative value would apply if the electron described the entire parabola, cutting the equipotentials.

Although the position of the electron at equipotential U_1 could be obtained from Eq. 4 or 7, and the process repeated at the next contour, the trajectory can be obtained more conveniently by constructing a universal family of curves from the second of Eq. 7. The curves are hyperbolas symmetrical about the axes, but not with common foci. Mutually reciprocal values of U_1/U_0 are associated with curves symmetrical about the $x = y$ line. The chart is thus as shown in Fig. 2, but only one half of it need be constructed for actual use.

Graphical Construction

To plot the path of an electron, a sheet on which the universal curves are plotted is placed on a map of the potential field as shown in Fig. 3. The lower edge of the chart is

(continued on p 162)

IT'S GLASS...

that gives extra performance to VITROTEX* MAGNET WIRE

ANACONDA VITROTEX magnet wire withstands temperatures up to 130° C., is highly flexible and has a remarkable space factor. All this is made possible by insulation of alkali-free glass —the ideal insulating material that is soft as silk and is comparable to steel in tensile strength.

Besides, Vitrotex offers high dielectric strength and a smooth surface that is resistant to moisture, acids, oils and corrosive vapors. For tighter, safer coils, to operate in confined spaces under high heat, make windings of Vitrotex. For details on the complete line of Anaconda Magnet Wire, write to Anaconda Wire and Cable Company, 25 Broadway, New York 4, New York.

*Reg. U. S. Pat. Off.

ANACONDA

Anaconda VITROTEX THE GLASS INSULATED MAGNET WIRE

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NEW PRODUCTS

Edited by A. A. McKENZIE

New equipment, components, tubes, testing apparatus and products closely allied to the electronics field. A review of catalogs, handbooks, technical bulletins and other manufacturers' literature

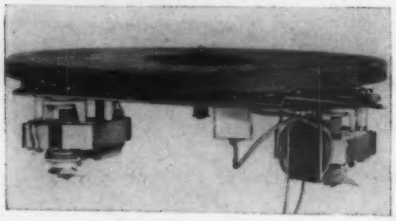
500-Mc Tube

RAYTHEON MFG. Co., Newton, Mass. Type CK5703 (formerly CK608CX) has a mutual conductance of 5,000 micromhos and amplification fac-

tor of 25. It has a 3-watt plate dissipation and can be made to produce about a watt of output power at 500 megacycles.

Old-New Record Turntable

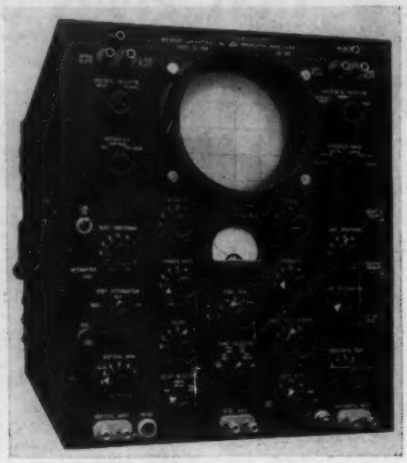
ALLIANCE MFG. Co., Alliance, Ohio. A new dual-speed turntable operating at either 33.3 or 78 rpm is a



modification of the model 80, containing two motors instead of one. Only one motor is used at a time.

Oscillosynchroscope

BROWNING LABORATORIES, INC., 742 Main St., Winchester, Mass. Model OL-15B Oscillosynchroscope includes a vertical amplifier bandwidth of 6 mc, recurrent sweeps of 5 to 500,000 per second and driven sweep rates of 0.25 microseconds per inch to 200 microseconds per



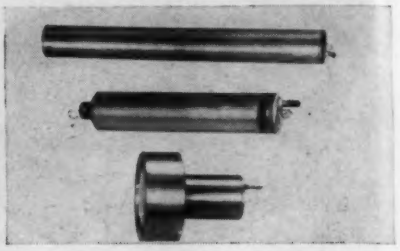
inch. The instrument is self-contained and uses a 5-in. cathode ray tube.

Ultrasonic Thickness Gage

PHOTOCON RESEARCH PRODUCTS, 1062 North Allen Ave., Pasadena 7, Calif. The Metroscope measures wall thickness of metal, plastic, and glass parts from one surface and will also detect flaws or imperfections in these materials. Using ultrasonic frequencies, the device operates on the basis of thickness vibrations, and gives a cathode-ray presentation of its findings.

Geiger Tubes

NUCLEAR DEVELOPMENT LAB., Box 7601, Kansas City, Missouri. Thin-



window, thin-wall, and all-metal cosmic ray counters illustrated are completely described in Bulletin 10.

Diversity Reception

DECIMETER, INC., 1428 Market St., Denver 2, Colorado. The DM-430 Diverse Adaptor selects the better

of two antennas for receiving the desired signal on as little as 0.05 volt of avc. It operates on 200 to 300 volts at 15 ma and filament supply of 6.3 volts a-c at 1.5 amperes.

Ceramic Microphones

ASTATIC CORP., Conneaut, Ohio. Two new microphones using ceramic elements are now available. Chief feature of the unit illustrated is its independence of high ambient temperatures. Its response is essentially flat from 30 to 10,000 cycles. Output level is minus 62 db. Recom-

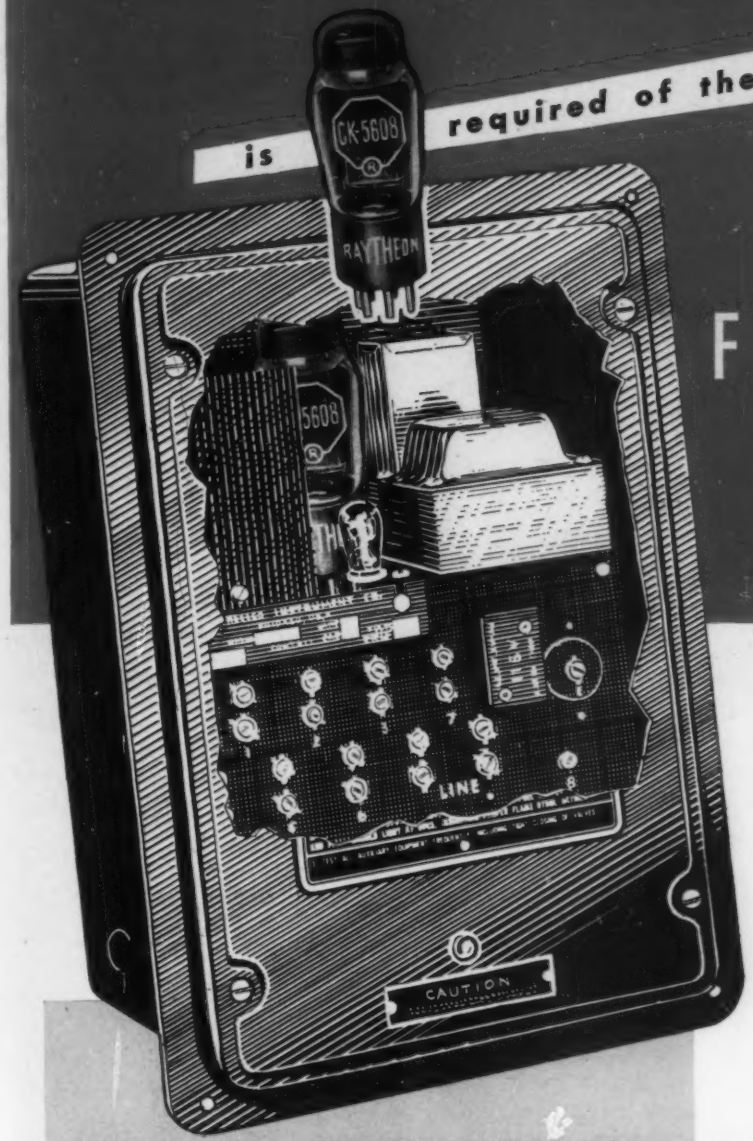
RAYTHEON RELIABILITY WITH A CAPITAL "R"

is required of the Raytheon Tube

in this WHEELCO

FLAME-OTROL

COMBUSTION SAFEGUARD



Wheelco uses a RAYTHEON CK-5608 Tube because of its *reliability* and *stability*—the result of:

1. Proven design and precise manufacturing control, backed by the experience of 25 years of continuous production involving $125,000,000.00 worth of special purpose tubes.

2. Unsurpassed engineering knowledge and ability in the development and manufacture of tubes especially to meet long life, industrial application.

Says the chief engineer of Wheelco Instruments Company, "We use this special Raytheon tube to be sure of uniform characteristics, long life and greater stability throughout its operating life."

The Wheelco Flame-Otrol guards life and property against the danger of explosion of any gas or oil fired furnace or industrial *heating* equipment. It does it ingeniously and positively by utilizing the electrical conductivity of *a gas flame or spectral response of an oil flame translating resistivity change or response of sensing element,* due to flame failure, through the use of a single Raytheon CK-5608 Tube, into change of current sufficient to operate a relay which acts to close the fuel valves. Action, being electronic, is instantaneous and sure.

Write for Detailed Information on RAYTHEON Special Purpose and Subminiature Tubes

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Excellence in Electronics

RAYTHEON MANUFACTURING COMPANY
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RADIO RECEIVING TUBES • SUBMINIATURE TUBES • SPECIAL PURPOSE TUBES • MICROWAVE TUBES

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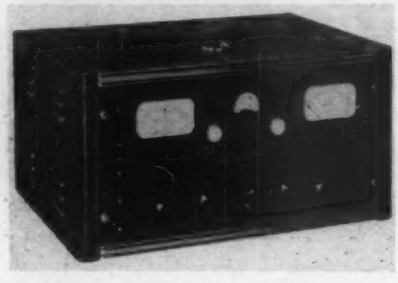
mended load impedance is 5 megohms.

Two-Speed Changer

MAGNAVOX Co., Fort Wayne 4, Indiana. A new two-speed record changer that makes it possible to play the new long-playing records at 33.3 rpm will also play conventional discs at 78 rpm. Pickup weight is 5 grams.

F-M Monitor

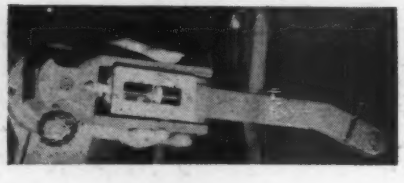
DOOLITTLE RADIO, INC., 7421 S. Loomis Blvd., Chicago 36, Ill. The FD-12 f-m frequency and modulation monitor handles up to four frequencies anywhere between 25 mc and 170 mc and has an accuracy of



0.0015 percent. A 500-ohm output is provided for audio monitoring. Power consumption is 80 watts.

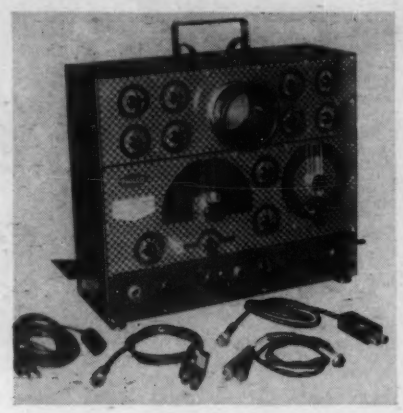
Tone Arm

GENERAL ELECTRIC Co., Syracuse, N. Y. A new tone arm equipped with a variable reluctance cartridge for playback of 10 and 12-inch records has a 1-ounce stylus pressure. Designated No. UPA-002, the unit is a companion to the professional transcription arm (illustrated) type FA-21-A with stylus pressure adjustable by means of a calibrated scale.



Alignment Generator

PHILCO CORP., Philadelphia, Pa., introduces a portable visual alignment generator, model 7008, for



television and f-m receivers, and for research and engineering work in frequencies from 3.2 to 250 mc. Price is $395.

Two-Jaw Clip

MUELLER ELECTRIC Co., 1583 East 31st St., Cleveland 14, Ohio. The new no. 22 clip has jaws at both ends. Either jaw or both may be opened by properly applied pressure. The clip is two inches long and has a screw connection. Free samples are available.

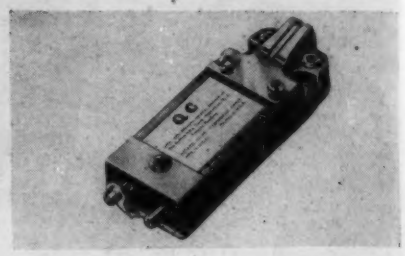
Lab Counter Set

EL-TRONICS, INC., Philadelphia, Pa. Model LS64 laboratory counter set is a complete instrument for use with Geiger counter tubes in measuring radiation intensities.

The unit has a built-in recording clock and uses the Higginbotham scaling circuit.

Ceramic Pickup

ASTATIC CORP., Conneaut, Ohio. Model QC pickup cartridge with



ceramic element has great physical ruggedness. It has a frequency range of 50 to 10,000 cycles and needle pressure of one ounce.

New Converters

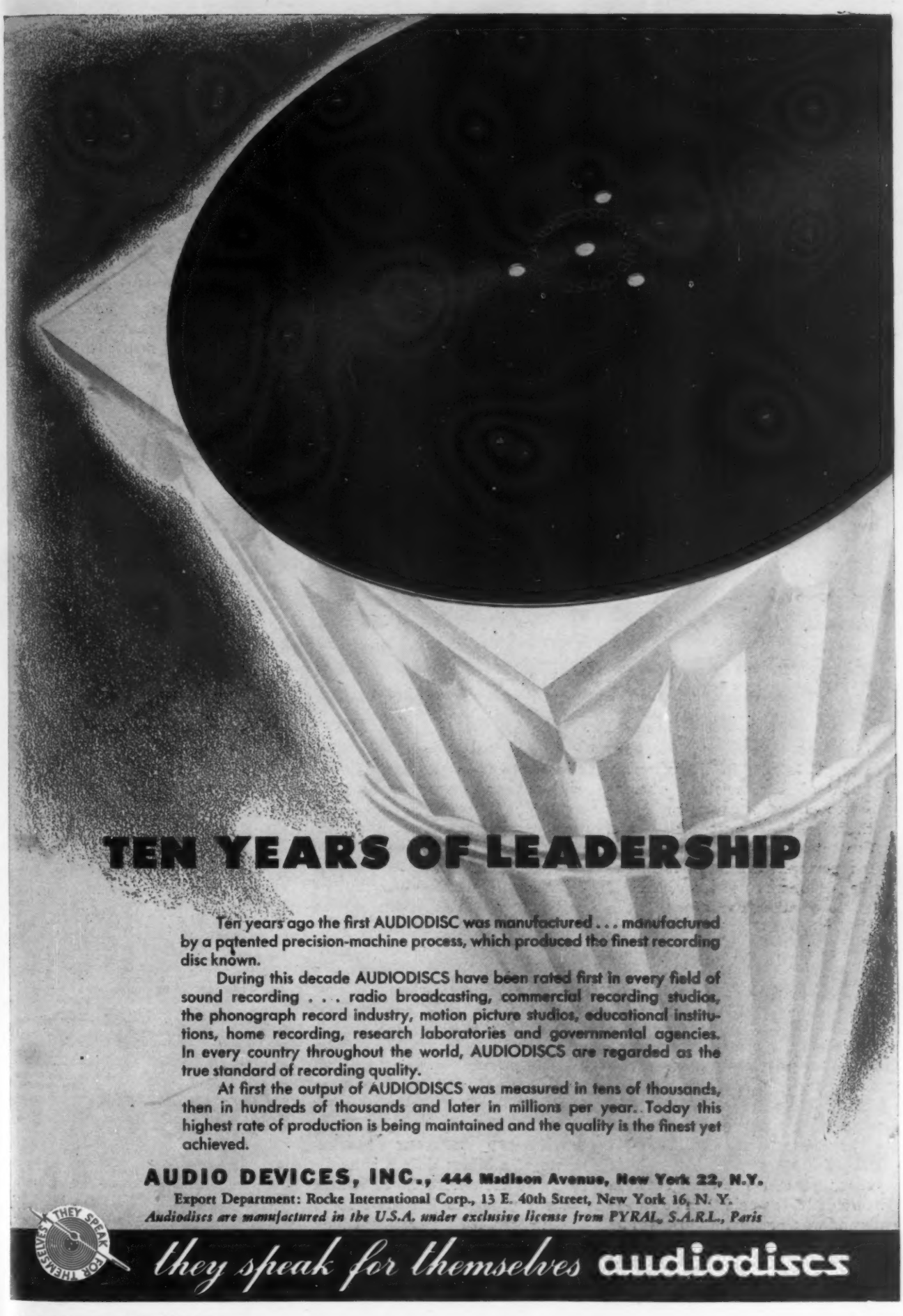
RADIO CORP. OF AMERICA, Harrison, N. J. Types 6BA7 and 12BA7 high-gain pentagrid converters are identical except for heater ratings. They have a conversion transconductance of 90 micromhos with 250 volts on the plate. The short inter-

nal leads are so designed for service in f-m broadcasting. A brochure is available.

UHF Signal Generator

BOONTON RADIO CORP., Boonton, N. J. Type 218 signal generator is a portable signal source for receiver measurements in the band from 400 to 1,000 megacycles. Maximum power output is 1 milliwatt

((Continued on p 182)


TEN YEARS OF LEADERSHIP
Ten years ago the first AUDIODISC was manufactured . . . manufactured by a patented precision-machine process, which produced the finest recording disc known.
During this decade AUDIODISCS have been rated first in every field of sound recording . . . radio broadcasting, commercial recording studios, the phonograph record industry, motion picture studios, educational institutions, home recording, research laboratories and governmental agencies. In every country throughout the world, AUDIODISCS are regarded as the true standard of recording quality.
At first the output of AUDIODISCS was measured in tens of thousands, then in hundreds of thousands and later in millions per year. Today this highest rate of production is being maintained and the quality is the finest yet achieved.
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they speak for themselves audiodiscs

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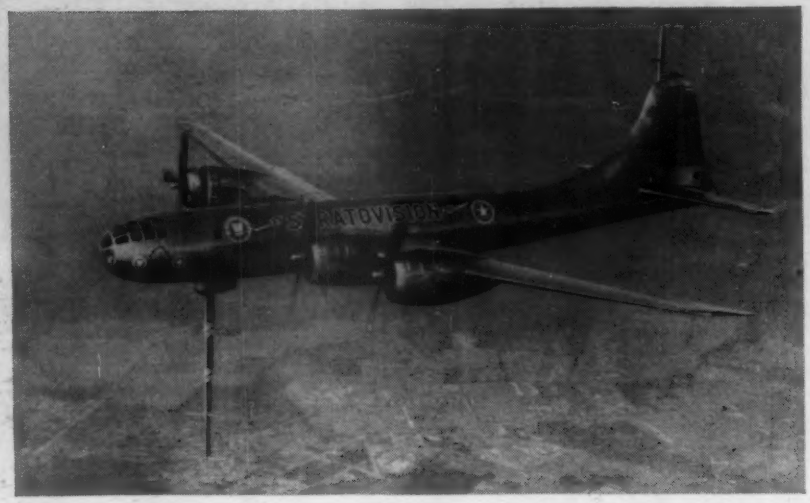
NEWS OF THE INDUSTRY

Edited by JOHN MARKUS

Rural industrial radio; URSI-IRE meeting; tv reallocation; Army tests transistors; utilities radio group; IRE-RMA Fall meeting

Stratovision Demonstration



Stratovision's flying television station over outskirts of Pittsburgh

RURAL AND SMALL town television coverage is now in the offing by means of Stratovision, whereas service in such areas could not otherwise be expected for years. A recent experiment in which some 40 reporters were flown to Zanesville, Ohio, was not too successful due to weather conditions, but a solution for the problem has been promised.

The principal purpose of the recent experiment conducted by Westinghouse and Glenn H. Martin Co. was to show the FCC why the sponsor should get channel 8 in Pittsburgh for regular ground service and Stratovision and why no other channel 8 station should be permitted within 200 miles of the city.

Immediate plans called for making KDKA-TV the conventional ground station operating several hours daily. It would then go off the air and would relay its programs by microwave to the plane, which would spray the channel 8 signal over a 200 to 250 mile radius.

Electronic equipment aboard the plane consists of a 5-kw video transmitter, the size of an ice-box; a 1-kw audio transmitter, intended to be placed in the same rack with the video; a transmitting mast 25 feet long, with 2 bays, lowering from the bomb-bay; and a receiving mast 8 feet long projecting from the tail fin.

The system when perfected would use four planes at each station. Two would alternate in the air, four hours at a time, while two were being serviced on the ground.

Highlights of RMA Convention

ANTICIPATED MILITARY requirements of a billion dollars annually for radio and electronics equipment recently prompted the RMA board of directors, led by president Max F. Balcom, to appoint an eight-man industry mobilization policy committe. The committee, appointed at the RMA's 24th annual convention in Chicago, consists of Fred R. Lack of Western Electric Co. as chairman, Paul V. Galvin of Motorola Inc., vice-chairman, Frank M. Folsom of RCA Victor, Harry A. Ehle of International Resistance Co., George R. Haase of Operadio Mfg. Co., H. L. Hoffman of Hoffman Radio Corp., W. A. MacDonald of Hazeltine Electronics Corp., and R. C. Sprague of Sprague Electric Co.

Objectives of the committee are to persuade government officials to establish a four-man committee to centralize and coordinate procurement of equipment and components, and to seek means of expediting production of military equipment through spreading work among all segments of the radio industry.

Other accomplishments of the convention were the reelection of Max F. Balcom as president of RMA for his second term, election of three new division chairmen and three new directors, re-election of 12 directors and two division chairmen, and the admission of 13 manufacturers as new members.

New division chairmen are: Set Division—George M. Gardner, president of Wells-Gardner & Co., Chicago; RMA Parts Division—A. D. Plamondon, Jr., president of the Indiana Steel Products Co., of Chicago; Transmitter Division—T. A. Smith of RCA Victor Division, Camden, N. J.; Tube Division—R. E. Carlson of Newark, N. J.; Amplifier & Sound Equipment Division—Fred D. Wilson of Operadio Manufacturing Co., St. Charles, Ill.

New directors are: Allen B. DuMont, president of Allen B. DuMont Laboratories, Inc., Passaic, N. J.; John W. Craig general manager of the Crosley Division of Avco Manufacturing Corp., Cincinnati, Ohio; and Herbert W. Clough, vice-president of Belden Manufacturing Co., Chicago.

The twelve directors who were reelected are: Benjamin Abrams, Max F. Balcom, W. J. Barkley, H. C. Bonfig, G. Richard Fryling, Samuel Insull, Jr., J. J. Kahn, F. R. Lack, W. A. MacDonald, A. D. Plamondon, Jr., Allen Shoup and G. W. Thompson. Retiring directors are past president R. C. Cosgrove, Lloyd A. Hammarlund and Monte Cohen.

Leslie F. Muter of Chicago was relected RMA treasurer for his fourteenth year, Dr. W. R. G. Baker of Syracuse, New York, was reelected director of the RMA Engineering Department. Bond Geddes was reelected executive vice-president.

Following are the 13 new members elected: Aircraft-Marine Products, Inc., Harrisburg, Pa.; Barnes Metal Products Company, Chicago 23, Ill.; David Bogen Co., Inc., New York 12, N. Y.; Consolidated Television Corp., New York 1, N. Y.; Drake Manufacturing Company, Chicago 22, Ill.; Electronic Tube Corporation, Philadelphia 18, Pa.; General Precision Equipment Corp., New York 7, N. Y.; Perfection Electric Co., Chicago 5, Ill.; Radio Specialty Mfg. Co., Portland 14, Ore.; Shure Brothers, Incorporated, Chicago 10, Ill.; Rowe Industries, Toledo 9, Ohio; Wirt Company, Philadelphia 44, Pa.; W. M. C. Inc., Chicago 47, Ill.

Following action by the RMA Set Division and upon recommendation of retiring chairman Paul Galvin,

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PROVIDES harmonic output voltages in 10 or 40 mc series with crystal-controlled accuracy.

SELECTS 10 or 40 megacycles series by means of front panel switch.

USED FOR calibration of receivers, wavemeters, or (with Beat Detector built into instrument) for calibration of oscillators and signal generators. May also be used in conjunction with a low-frequency communications-type receiver to determine UHF oscillator drift. A mixer unit is available for this application.

Completely portable Accuracy 0.1% Models available from 100 to 2000 megacycles with 2 to 1 frequency coverage on each model.

RECOMMENDED FOR:

- Production testing
- Measurement of oscillator drift
- Independent alignment of transmitters and receivers
- Precise measurements of frequencies

FULL DETAILS ON REQUEST

Lavoie Laboratories

RADIO ENGINEERS AND MANUFACTURERS

MORGANVILLE, N. J.

***Specialists* in the Development and Manufacture of UHF Equipment**

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Fred R. Lack, vice-president of Western Electric, addressing membership luncheon at annual convention of RMA in Chicago

the board of directors voted to continue the policy not to sponsor or endorse any public or trade shows of television or radio receivers. The board also adopted a resolution asking the FCC to retain the present numbers of the twelve television channels for the avoidance of confusion.

Finally, associate director Virgil Graham reported that the Rochester Fall Meetings in the future will be under the sponsorship and direction of the RMA Engineering Department in cooperation with the IRE, instead of the Rochester Fall Meeting Committee which originated these annual engineering conferences.

Instrumentation Conference

A THREE-DAY conference on electronic instrumentation in medicine and nucleonics, jointly sponsored by the AIEE and IRE, is scheduled to be held in New York City, Nov. 29 to Dec. 1, 1948. Arrangements are to have the area of common interest fall on the second day of the meeting. On the first day, devoted to electronic aids to medicine, such items as biological amplifiers and recording devices (c-r oscillograph, electrocardiograph and electroencephalograph) will be covered. The second and third days will cover nucleonic instrumentation, including subjects of interest in medicine and physics. The second of these three days will be devoted to matters of interest to medical personnel, including stable isotope measurement.

Further information on the conference and registration may be obtained by writing to C. C. Wilson, AIEE Headquarters, 33 W. 39th St., New York 18, N. Y.

Soviet Television

INDICATIVE of the status of television in the USSR is the fact that one electrical appliance store in Moscow now has on sale to the general public the Moskvich T-1 television receiver. It is a 20-tube set with combination f-m radio reception but only an adapter for record-playing.

However, reconstruction work is being carried out at the Moscow Tele-Center television broadcasting station, which is still using 343-line pictures, for changeover to 625-line pictures. Image clarity at the Leningrad center has been increased to 441-line pictures compared with the prewar 240-line images. Regular

(Continued on p 212)

MEETINGS

AUG. 20-29: All-Electrical Exposition, Pan-Pacific Auditorium, Los Angeles, Calif.

AUG. 24-27: AIEE Pacific General Meeting, Spokane, Wash.

AUG. 30-SEPT. 17: 114th national meeting, American Chemical Society. Eastern session, Washington, D. C., Aug. 30-Sept. 3; midwest session, St. Louis, Mo., Sept. 6-10; western session, Portland, Ore., Sept. 13-17.

SEPT. 4-6: ARRL Convention, Milwaukee Auditorium, Milwaukee.

SEPT. 6-11: International television meeting, with exhibition Sept. 2 to 15, Swiss Federal Institute of Technology, Zurich. Address inquiries to Secretariat, International Television Meeting, Gloriastrasse 41, Zurich 6, Switzerland.

SEPT. 13-17: Third Instrument Conference and Exhibit, Convention Hall, Philadelphia, Pa.

SEPT. 20-23: Annual meeting, Associated Police Communication Officers, Inc., Rice Hotel, Houston.

SEPT. 27-OCT. 1: Third National Plastics Exposition, Grand Central Palace, New York City.

SEPT. 29-OCT. 2: Pacific Electronic Exhibition and IRE west coast Annual Convention, Biltmore Hotel, Los Angeles, Calif.

OCT. 5-7: AIEE Middle-Eastern District Meeting, Washington, D. C.

OCT. 7-9: Second joint meeting, URSI and IRE, National Bureau of Standards, Washington, D. C.

OCT. 11-12: PM Association Second Annual Convention, Sheraton Hotel, Chicago.

OCT. 12-16: Fifth National Chemical Exposition, Coliseum, Chicago, Ill.

OCT. 23-29: Annual convention, American Society for Metals, Benjamin Franklin Hotel, Philadelphia.

OCT. 25-28: Annual Fall meeting of the Institute of Metals, Division, American Institute of Mining and Metallurgical Engineers, Hotel Adelphia, Philadelphia.

OCT. 25-29: National Metal Exposition, Commercial Museum and Convention Halls, Philadelphia.

OCT. 25-29: Annual Convention, American Welding Society, Bellevue-Stratford Hotel, Philadelphia.

OCT. 25-29: 64th semiannual convention, Society of Motion Picture Engineers, Hotel Statler, Washington, D. C.

OCT. 27-28: Annual Convention, Society for Non-Destructive Testing, Hotel Adelphia, Philadelphia.

NOV. 4-6: National Electronics Conference, Edgewater Beach Hotel, Chicago.

NOV. 8-10: Twentieth Rochester Fall Meeting of members of IRE and RMA Engineering Dept., Sheraton Hotel, Rochester, N. Y.

NOV. 29-DEC. 1: Conference on electronic instrumentation in nucleonics and medicine, sponsored by IRE and AIEE, Engineering Societies Building, New York City.

NOV. 29-DEC. 4: 18th National Exposition of Power and Mechanical Engineering, Grand Central Palace, New York.

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1	**FTR 3300-DS**	D-C Output—2-32 volts, 50 amperes A-C Input—115 volts, 1-phase, 60 cycles
2	**FTR 3339-BS**	D-C Output—6-24 volts, 18 amperes A-C Input—115/230 volts, 1-phase, 50/60 cycles
3	**FTR 3128-BS**	D-C Output—22-30 volts, 10 amperes (filtered and regulated) A-C Input—115 volts, 1-phase, 60 cycles
4	**FTR 3341-AS**	D-C Output—28 volts, 5 amperes A-C Input—115 volts, 1-phase, 50/60 cycles
5	**FTR 3246-BS**	D-C Output—6 volts, 10 amperes (filtered) A-C Input—115 volts, 1-phase, 60 cycles
6	**FTR 1342-AS**	D-C Output—6 volts, 4 amperes (3 cells 6-3 amperes) A-C Input—115 volts, 1-phase, 50/60 cycles

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Finest quality, high efficiency, 30-watt power capacity, frequency response from 60 to 15,000 cycles—that's the *unequaled combination* of features you get in the Western Electric 757A. It's ideal for the finest audio systems, for broadcasting or sound distribution.

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Western Electric

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(continued from p 122)

10 to 80 C. For this reason, less heating time is required in testing gas-filled tubes.

In general testing, a few points should be reviewed before a tube has definitely been considered bad:

Heater voltage at the heater terminals of the tube must be at the rated value. Any poor connection on one of the heater terminals will cause a lowering of voltage at the terminal with a resulting lowering of cathode temperature and an increasing voltage drop from anode to cathode during conduction.

The anode, cathode, and grid leads of thyratrons must make good contact with the caps of the tester to insure proper current conduction.

Sensitive Transducer

A DEVICE for electrically measuring mechanical motions or displacements that places no friction load on the transmitting device and exerts little or no reaction force on the transmitting device, is the Atcotran. It has a linear electrical response when actuated by a linear mechanical motion and operates from 60-cycle current.

Essentially the Atcotran is a differential transformer with a linear response. It consists of three coils as shown in Fig. 1. These are

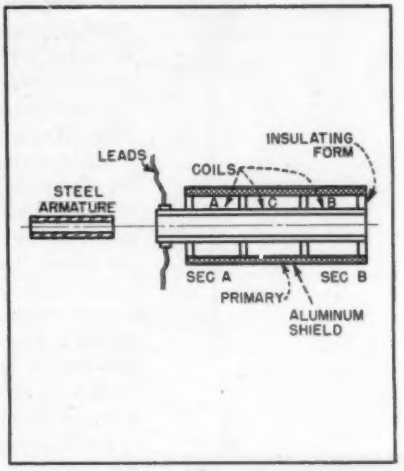


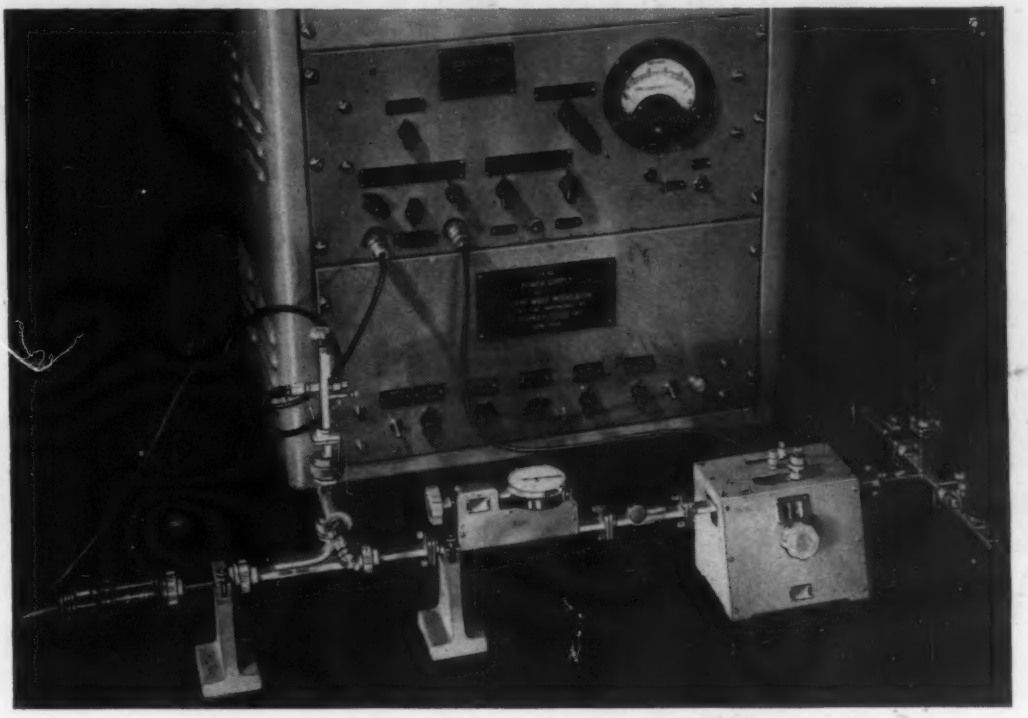
FIG. 1—Cross-section of coil assembly

wound on a single spool, with a free-moving armature of magnetic material mounted inside the spool.

Alternating current is supplied to the center or primary coil *C* and the magnetic flux generated by this coil is distributed by the armature so

DE MORNAY • BUDD
STANDARD TEST EQUIPMENT

For Precision Broad Band Microwave Measurements



A typical, K Band, bench test set-up with power supply and amplifier

The complete line of De Mornay-Budd standard test equipment covers the frequency range from 4,000 mcs to 50,000 mcs. It provides all R. F. waveguide units necessary for broad band precision test work requiring extremely high accuracy in attenuation measurements, impedance measurements, impedance matching, calibration of directional couplers, VSWR frequency measurements, etc.

To eliminate guesswork, each item of this De Mornay-Budd test equipment is individually tested and, where necessary, calibrated, and each piece is tagged with its electrical characteristics. All test equipment is supplied with inner and outer surfaces gold plated unless otherwise specified.

DE MORNAY BUDD

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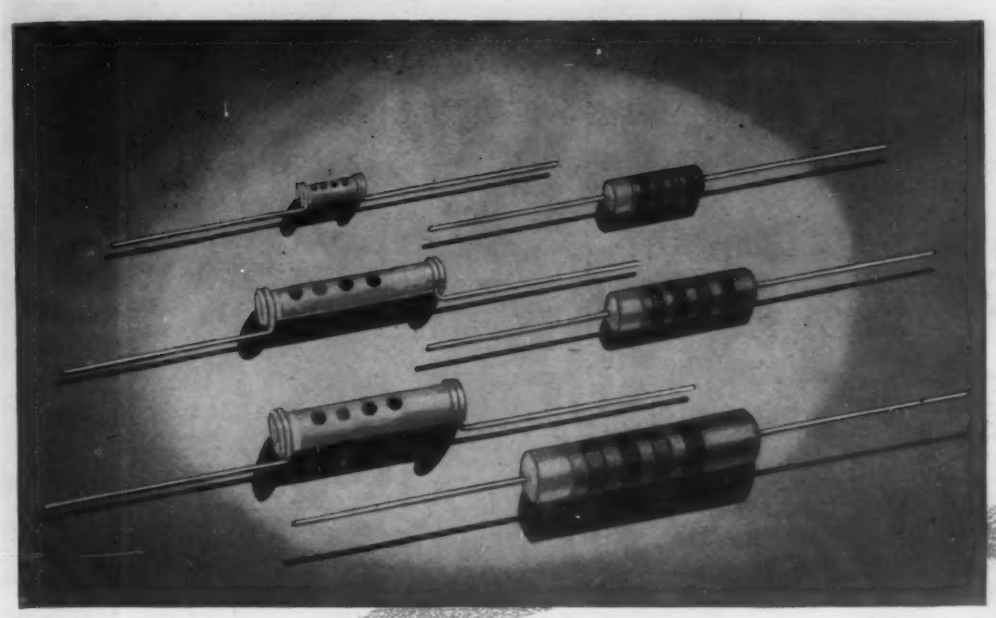

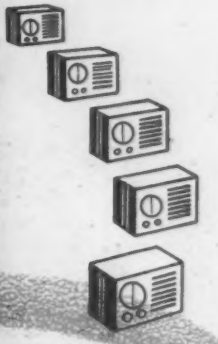

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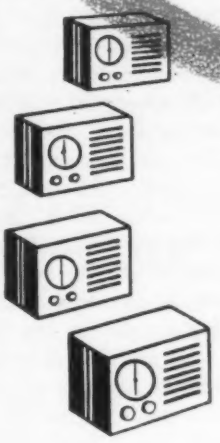

ERIE "GP" Ceramicons are small and compact, even in high capacities. Tubular in shape, they require less space than rectangular condensers. They can be wired into position more easily and quickly where space conditions are close, and thus are basically easier to handle in any type of installation.

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The enormous popularity of "GP" Ceramicons is the result of a combination of their superb performance and economical cost. Their inherently simple construction results in higher resonant frequencies that are so important in by-passing applications for FM and Television.

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Electronics Division

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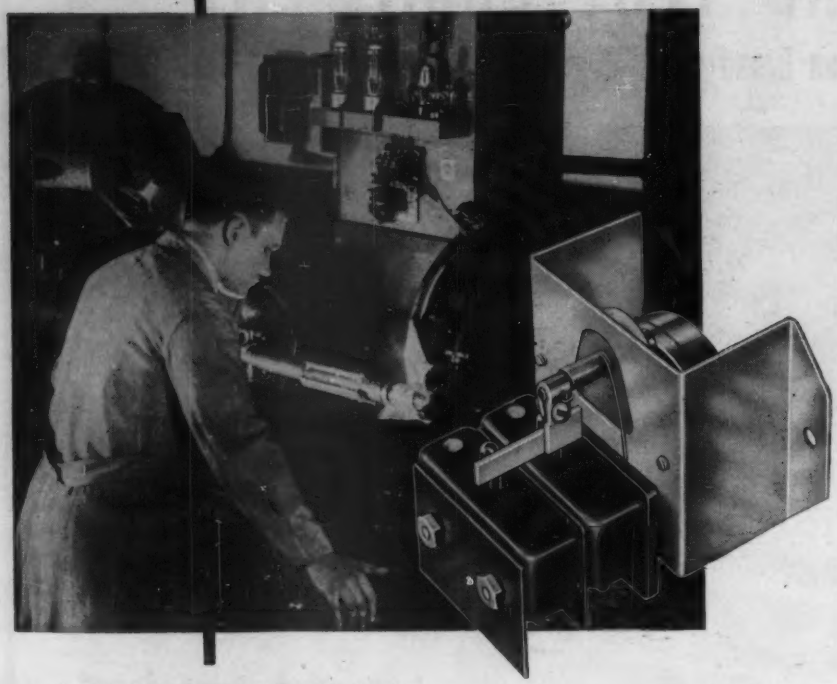
FOR A-C CIRCUITS Provides centralized control for simple action. Features starting, quick-stopping, jogging, inching or creeping, reversing, with infinite speed adjustments and controlled acceleration and deceleration.



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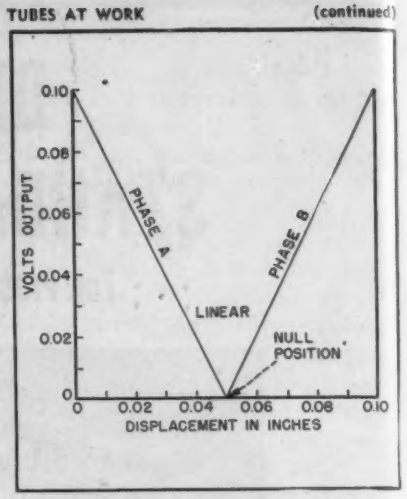

FIG. 2—Output voltage as a function of movement of the armature

that a voltage is induced in secondary coils *A* and *B*.

If the armature is symmetrically located (centered), the induced voltages will be equal but if the armature moves to the left the induced voltage in coil *A* will be greater than that induced in coil *B*. If the armature moves to the right the voltage in coil *B* will be greater than that induced in coil *A*.

In normal operation, coils *A* and *B* are connected in a series bucking relationship so that, when the armature is centered and both coils have equal voltages induced into them, the resulting output will be zero. If the armature moves to the left a voltage of one phase A will predominate, and if the armature moves to the right a voltage of the other phase B will predominate. Phase A will differ from phase B by 180 degrees. These relations are illustrated in Fig. 2.

If the unit were connected as il-

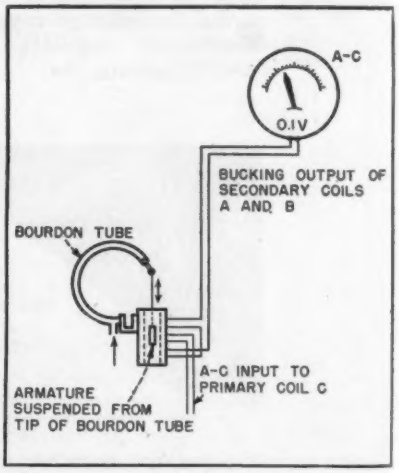
A-C
0.1V
BUCKING OUTPUT OF SECONDARY COILS A AND B
BOURDON TUBE
A-C INPUT TO PRIMARY COIL C
ARMATURE SUSPENDED FROM TIP OF BOURDON TUBE

FIG. 3—Application of the pick-up unit to a Bourdon tube for pressure measurements

THE new alarm-lock works easily enough when you know the right buttons to push. Push the wrong ones, and you bring the cops on the run. Like so many other signaling devices, the alarm-lock is operated by a Telechron synchronous electric motor.

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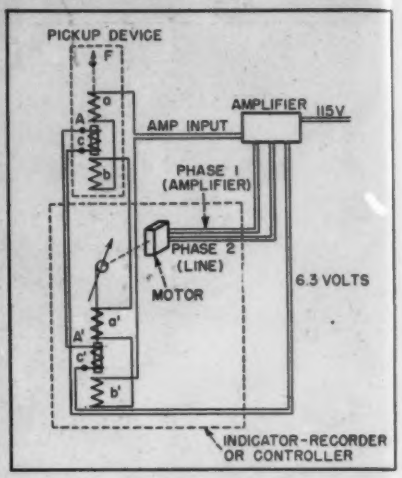

FIG. 4—Two Atcotrans in a balance circuit for remote indication or control

lustrated in Fig. 3, and if the portion of the curve in Fig. 2 between 0.05 and 0.1 inch were used, the a-c meter pointer would go from zero to full scale for a Bourdon tube deflection of 0.05 inch. The meter could readily be calibrated in terms of pressure as applied to the Bourdon tube.

A null-balance circuit is shown in Fig. 4.

When both Atcotran armatures are in their proper position the outputs of Atcotrans *A* and *A'* will be equal and opposite in phase and the resultant input to the amplifier will be zero. No voltage will be applied to the amplifier phase of the motor and it will be dominant.

When the pickup device raises the armature of Atcotran *A*, phase A will predominate and the input to the amplifier and subsequent input to the motor will be in the proper phase relationship with the line voltage to run the motor and raise the armature of *A'* Atcotran a like amount and balance the system.

If the pickup device lowers the armature of Atcotran *A*, phase B will predominate and the motor will run in the opposite direction until the system is again rebalanced. In this way the motor will continually cause the armature of Atcotran *A'* to follow the movements of the pickup, and any pointer or pen coupled to the motor shaft will indicate or record a motion exactly proportional to the motion of the pickup, which in the case of a Bourdon tube is in turn proportional to the pressure applied to it. Such an arrangement will result in a remote pres-

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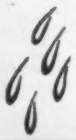

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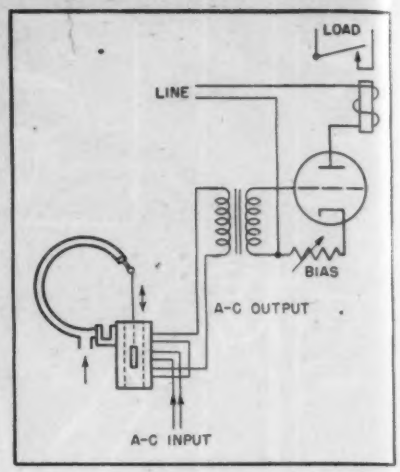

FIG. 5—Electronic phase and voltage-sensitive relay

sure transmission system of unusual stability and accuracy.

Another arrangement is shown in Fig. 5. The electronically operated relay will pull in and either close or open a load circuit, when a small a-c voltage is applied to its input terminals. The magnitude of this voltage required to operate the relay is determined by the bias control. When the Atcotran armature is in a phase A relationship the relay will not be actuated, but if its armature moves through the null or zero output position (see Fig. 2) to a phase B position, the relay will pull in and actuate a load circuit. Such an arrangement would give off and on control of pressure or could be used as an alarm.

If two electronic relays were used —one connected to pull in on A phase and one on B phase and the bias controls were properly adjusted we would get three-position (High—Neutral—Low) control.

Since the Atcotran made by Automatic Temperature Control Co., is a voltage-producing device a number of these units may be connected in series to give an electrical output which is either the sum, difference or average of a plurality of variables.

Video Interference

AS MEMOED to designers and manufacturers of television receivers by I. J. Kaar, chairman of RMA Committee on Television Receivers, there is a serious problem of radio interference that may be caused by

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video and scanning circuits of television receivers.

Since the range from 10 kilocycles to 4,500 kilocycles is coincident with those frequencies used in radio communication and radio broadcast, it is to be expected that wiring and components in the television receiver which carry video currents may possibly radiate or produce induction fields of sufficient strength to cause interference to other services employing radio frequencies.

Interference in the broadcast band is of particular importance because receivers for this band may be located in an adjacent room in an adjoining apartment in the same building so that possibly only a few feet may separate the broadcast and the television receivers. The video interference usually sounds quite mushy and makes itself evident as a noisy background of variable intensity riding along with the broadcast program. The intensity may be so severe in some cases as almost to obliterate completely weak broadcast signals. In addition to the mush there may be birdies or tweets caused by more or less steady frequency components in the video signal beating with the carrier.

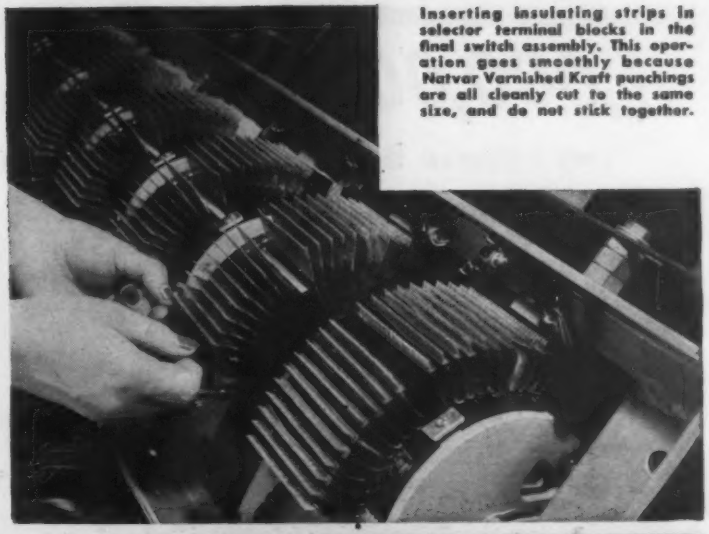
Intercarrier Audio

A third type of interference may be found at 4,500 kilo-cycles, in a band used at airports and for some fixed and mobile services. This frequency is found in video circuits as a result of detection of the television sound carrier by the television picture second detector since the difference between the picture and sound carriers is 4,500 kilocycles. This 4,500-kilocycle signal will be frequency modulated by the television sound signal and may be readily identified and received by using slope detection in a standard a-m receiver.

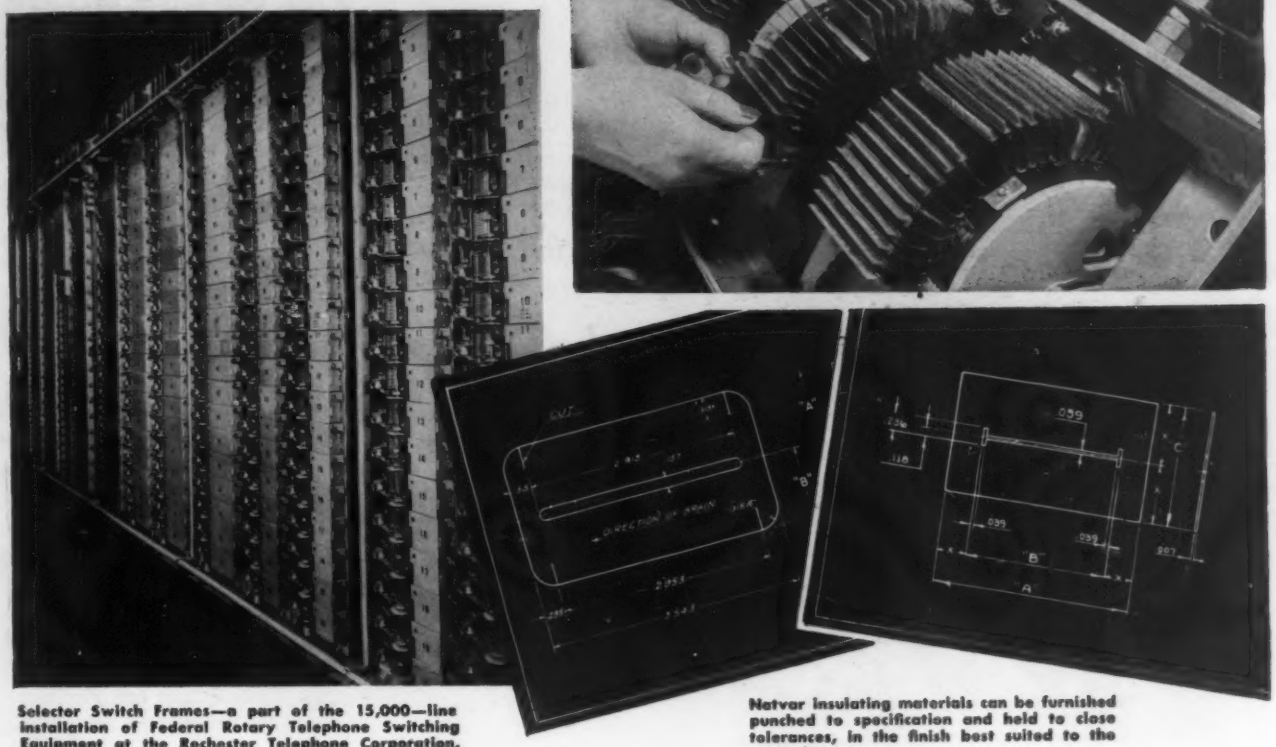
In one instance the 4,500-kilocycle signal interfered with airport operations at an airport located over a mile from the offending receiver. An examination of the receiver revealed that the installation was a custom-built one wherein the video frequency conductor from the last video amplifier to the cathode-ray tube was over ten feet in length and unshielded.

In general, video interference can

Compact... Dependable



Inserting insulating strips in selector terminal blocks in the final switch assembly. This operation goes smoothly because Natvar Varnished Kraft punchings are all cleanly cut to the same size, and do not stick together.



Selector Switch Frames—a part of the 15,000—line installation of Federal Rotary Telephone Switching Equipment at the Rochester Telephone Corporation, Rochester, N. Y.

Natvar insulating materials can be furnished punched to specification and held to close tolerances, in the finish best suited to the operation.

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Descriptive Bulletin No. 10 Available

BALLANTINE LABORATORIES, INC.

BOONTON, NEW JERSEY, U.S.A.

be reduced by using short connecting wires shielded by running them in fairly close proximity to conductors at r-f ground potential. A brute-force method would be to enclose the whole receiver in a cabinet having a screen shield built completely covering its inner surface. Screening cannot be put over the face of the picture tube, so some radiation occurs through the face of this tube. In an experimental receiver the residual interference was further reduced by employing a picture tube having a special conductive but translucent coating applied to its face and grounding the coating to the chassis.

Scanning Circuits

Scanning systems develop pulse-type and sawtooth-type waves having fairly steep decay characteristics (short-time decay). An analysis of the frequency spectrum reveals the presence of fairly strong harmonics of the line (horizontal) and field (vertical) frequencies. The harmonics of the field frequency, being harmonics of 60 cycles per second, are ordinarily not bothersome at radio frequencies because the amplitude usually falls off inversely with the order of the harmonic.

This is not true in the case of the horizontal frequency because the fundamental is 15,750 cycles per second, and is therefore itself a radio frequency. Harmonics of sufficient amplitude to cause interference to broadcast service have been observed. This type of interference makes itself evident in the form of birdies or tweets caused by the harmonics beating with the broadcast station carriers.

This type of interference is quite annoying and does not change in intensity with picture content, but may change in intensity if the size and linearity controls are adjusted or if a person walks up to a television receiver and changes the radiated field intensity by an antenna effect. A satisfactory cure for this type of interference has been found by the employment of grounded shielding. The components requiring shielding usually are the sweep yoke, the high-voltage rectifier system for the picture tube second anode if the h-v supply is

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12E2237	Magneto Dynamic	—	2.15 lbs.	12"
15E3017	Electro Dynamic	3 lbs.	—	15"
15E1037	Magneto Dynamic	—	1.00 lb.	15"
15E1537	Magneto Dynamic	—	1.47 lbs.	15"
15E2237	Magneto Dynamic	—	2.15 lbs.	15"

The 12" size will handle 15 watts maximum speech music audio power and the 15" size, 18 watts.

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derived by the "kick" across the horizontal output transformer, the horizontal sweep amplifier tube and horizontal sweep-damping tube, if employed.

Visual Examination of Crystal Modes

USE of the Megasweep, a sweeping oscillator with output between 50-kc and 500-mc (ELECTRONICS, Aug. 1947, p 112), makes possible the visual observation of crystal modes.

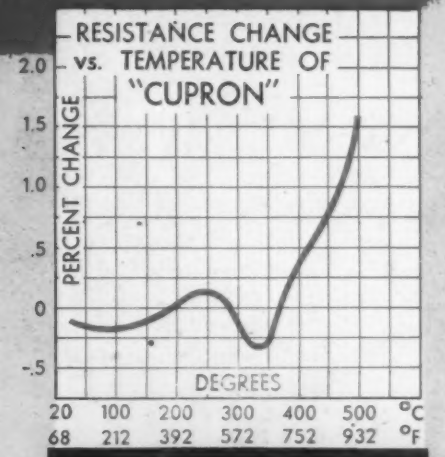
The sawtooth sweep voltage of the sweeping oscillator is applied to the horizontal plates of an oscilloscope, providing a horizontal deflection which is proportional to frequency. The frequency-modulated output signal of the sweeping oscillator is applied across a quartz crystal; and the voltage across the crystal, after rectification and filtering, is passed on to the vertical deflecting plates of the oscilloscope. With the sweeping oscillator adjusted for maximum sweep, the oscilloscope pattern will show those crystal modes lying within the sweep width.

The maximum sweep of the instrument is usually about 30 mc, but it can, with some loss of linearity, be brought up to about 70 mc. As the sweeping frequency passes through the crystal frequency or one of its odd harmonics, the crystal impedance and the rectified voltage across it become minimum. Since this absorption occurs periodically at the sweep rate, a stationary pattern is seen on the oscilloscope with pips corresponding to the series resonant modes of the crystal.

As the center frequency of the sweep is shifted, higher modes can be seen to appear on the pattern. With the sweeping oscillator adjusted for narrow sweep, the pattern of an individual "pip" occupies a large area on the oscilloscope and can be studied in detail.

In a typical test using a 10-mc fundamental crystal, the modes were traced up to the 11th, a frequency of 110-mc. The size of the pips was noticeably different, the variation being due either to different mode strengths or amplitude

Photomicrographics are only part of the story...



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Max. R.F. Load	70KVA	50KVA	45KVA	25KVA	40KVA
Peak Voltage	7.5KV	7.5KV	7.5KV	7.5KV	7.5KV
Max. R. F. Current	30 Amps.	30 Amps.	30 Amps.	30 Amps.	30 Amps.
Body Dimensions	1¾" × 3½"	1¾" × 3½"	1⅝" × 3½"	1¾" × 3½"	1⅝" × 3½"

★ Lead-through type, all other examples tag type.

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modulation in the output. Using the wavemeter incorporated in the instrument, the frequencies of the modes were measured and found to be 20-mc apart.

Acoustic Well Sounder

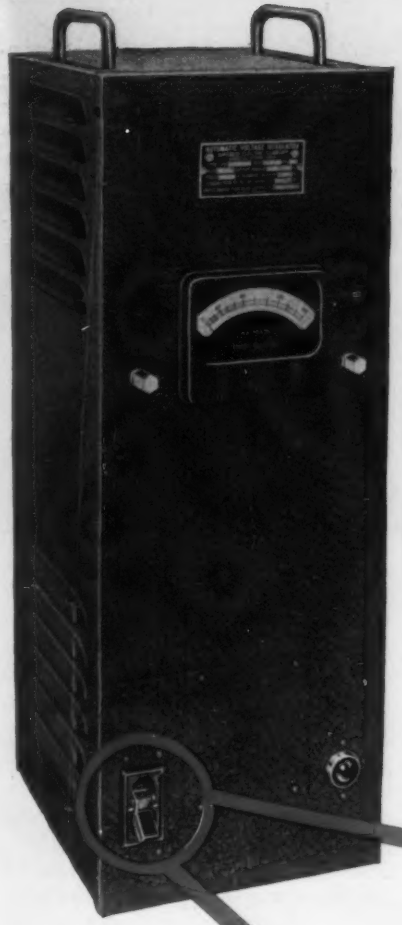
DETERMINATION of the fluid level in the annular space between the casing and the tubing of an oil well is being done with an acoustic method.

A small pressure-tight chamber attached to a casing outlet at the surface of the ground contains a microphone and a mechanism for firing a blank cartridge. The sound of the explosion travels down the annulus between the tubing and the casing; the sound is partially reflected at all obstructions such as tubing collars and tubing catcher, and is finally reflected almost totally at the top of the column of oil which usually extends some distance above the pump.

The sound of the initial explosion, and also all of the reflected pulses are transformed into an electric current by the microphone within the chamber attached to the well-head. This current is amplified and recorded on a moving strip of paper by means of two pen-and-ink recording galvanometers operating simultaneously.

The reflection from the top of the fluid appears on the record as a large disturbance superimposed on a succession of small kicks which result from the weak reflections at the tubing collars. Thus the top of

Well attachment ready for firing. Sound traveling down is partially reflected by obstructions and surface of oil



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In the above equipment the Circuit Breaker is installed in the brush lead of the Powerstat variable voltage transformer. When the load exceeds the current rating of each individual transformer, the Circuit Breaker opens, thus eliminating any chance of injury to any part of the equipment.

These breakers are *instantaneous* on short circuit, but a magnetic-hydraulic time delay mechanism allows passage of slight, temporary overload. If this overload continues beyond the time-delay limit, the breaker trips. Magnetic blowout provides high and fast interrupting capacity.

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IT'S A PACESETTER . . . a major new accomplishment in terms of quality performance at modest cost. And, still, that is only part of the story of this new Astatic Microphone. It has usability unlimited! It is so designed that it may be used in a variety of ways shown in illustrations. Extra convenience in all applications is offered by optional models with Type "S" off-on switch. Crystal and Ceramic models furnished in dark brown, streamlined plastic case; Dynamic models in die-cast case.

Work on AC-DC or standard circuits. Crystal and Ceramic models available with substantially flat response or rising characteristics in the voice range. Dynamic models incorporate Astatic's newly developed circular, Alnico 5 magnet, which doubles flux density, providing higher output level, extended range, and more stability, permitting highest quality performance in these more compact units. CB Base, stand adapter and hang-up bracket are accessories, and may be purchased separately.

Write for prices, additional details

SPECIFICATIONS

Model No.	Type	Recommended Load Impedance	Output Level (Approx.)	Freq. Response c.p.s.	Characteristics
OS	Crystal	5 Meg	—50 db	30-10,000	Substantially Flat
OS-1	Crystal	5 Meg	—50 db	30-10,000	Rising Characteristics
OD	Dynamic	500 Ohm	—62 db.	30-10,000	Substantially Flat
ODH	Dynamic	5 Meg	—50 db.	30-10,000	Substantially Flat
OSC	Ceramic	5 Meg	—62 db	30-10,000	Substantially Flat
OSC-1	Ceramic	5 Meg	—62 db.	30-10,000	Rising Characteristics

Listed in The Radio Industry RED BOOK

Astatic Crystal Devices Manufactured under Brush Development Company patents

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ASTATIC
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the fluid is located with reference to the natural scale of tubing collars. The interpretation of the record requires only the counting of the number of tubing joints exposed above the fluid.

As employed in the Keystone Sonolog, the two simultaneous recording channels are adjusted permanently for best response to different events, which makes it possible to dispense with critical adjustments, and semiskilled personnel obtain satisfactory results.

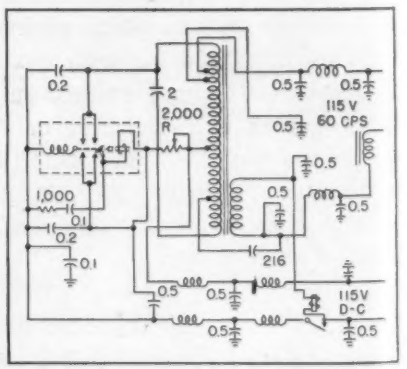
The instrument is designed for portable operation and consists of three components, the well-attachment, the amplifier-recorder and a power converter operating from a six-volt storage battery. The log is available immediately without any intermediate processing since pen and ink are used.

Power Converters for Television

OPERATION of television receivers from a d-c power line can be accomplished by using the vibrator-type converter whose circuit is shown in the diagram. It incorporates a frequency control (potentiometer *R*) which permits adjusting the vibrator to a frequency of 60 cycles to prevent distortion of the picture.

Although most cities are supplied exclusively with a-c power lines, there is still a significant number that contain d-c districts. New York City, for example, has 316,000 d-c meters, Boston has 58,000, and Chicago has 26,000. And television stations are now operating in all three cities.

The circuit shown is that of one



Adding potentiometer *R* to a vibrator power supply permits frequency adjustment

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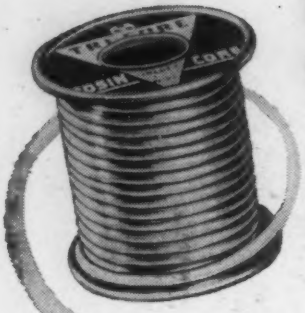

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- ★ Adapted to your production needs: an American solder designed for American production; manufactured and stored here ready for delivery!
- ★ No toxic, obnoxious fumes!
- ★ 25% more joints per hour per pound of solder!
- ★ Cut your solder cost with Tri-Core's — 5 to 15% less tin and still get better results than possible with other solders using more tin.
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converter made by Electronic Laboratories. It is filtered to less than one microvolt throughout the f-m and television bands, and powers a receiver rated up to 230 watts. A second model supplies up to 475 watts. These ratings are applicable to equipment having a high power factor, from 80 to 100 percent, such as is normally found on transformer-operated devices.

Baseline for Visual Alignment Systems

By Elliott A. Henry

Globe Products Corp.
Bridgeport, Conn.

Activity in the television field has stimulated interest in sweep-frequency generators and visual alignment systems. The time saving and ease of adjustment inherent in visual systems outweigh the initial cost of equipment and the difficulty in making accurate gain measurements. Precise gain measurements, as well as a more accurate picture of the gain-frequency characteristic of the amplifier or net work, may be obtained if a reference of zero voltage (baseline) is provided on the cro screen.

The baseline may be obtained by blanking the return sweep within the sweep generator or by blanking the input of the vertical amplifier of the cro. As the majority of sweep generators do not incorporate internal blanking, and as physical or electrical considerations present conversion problems, the latter method is to be preferred.

While electrical blanking, obtained by keying one of the cro amplifier stages, might be used, it will not produce satisfactory results as the d-c component of the rectified

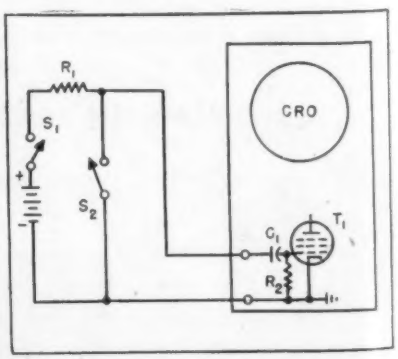

FIG. 1—Simplified circuit using battery to charge capacitor

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- Precision ground, stainless steel, double thread, lead screw guides the rotating contact, *guarantees* smooth action, low uniform torque and accurate settings — *permanently*.
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wave will be lost in coupling to the cro and a d-c component, equal to the plate voltage difference of the keyed stage, will be added and appear on the cro screen. Since it is necessary, to produce an accurate picture of the gain-frequency characteristic of the network under test, to transfer the d-c component of the rectified wave to the cro screen and since this is readily accomplished by periodically restoring the cro vertical amplifier to its zero operating condition, mechanical blanking was chosen.

Basic Operation

For an explanation of the transfer of the d-c component, reference is made to Fig. 1. With switch 2 open, when switch 1 is closed, with the battery polarity as shown, C_1 charges through R_1 and R_2. The direction of current flow makes the grid of T_1 go positive and the cro spot to move upward. When C_1 becomes fully charged, current ceases to flow and the grid returns to its static value. The spot returns to its former position and nothing further happens as long as conditions remain unchanged.

Now if switch S_2 is momentarily depressed, C_1 will be discharged through R_2 while the battery will be protected by R_1. The direction of current flow is now such as to make the grid of T_1 go negative and the cro spot to move downward. Therefore if S_2 is made to operate rapidly and to have equal off and on time, the pattern obtained will be a series of square waves, the magnitude of which will be an absolute proportionality to the battery voltage as C_1 has had a charge alternating between zero and full battery voltage.

By substituting the load of the linear diode detector for the battery, adjusting switch S_2 on-time to 180 degrees of the modulation cycle, and providing a means of phasing the start of S_2 on-time, either the up or down sweep may be blanked and the baseline, equivalent to zero voltage, obtained.

Resistor R_1 should have a value at least four times greater than the diode load resistor to prevent the discharge of the diode capacitor during switch S_2 on-time. Switch S_2 must be capable of very fast action and have very low contact resistance. A relay with the mercury-

for HIGH Resistances

SPECIFICATIONS

RANGE: 2,000 ohms to 50,000 megohms in five overlapping ranges; zero to 100 volts, d-c as a vacuum-tube voltmeter.

ACCURACY: within ±5% of indicated value from 30,000 ohms to 3 megohms; within ±8 % from 3 to 3,000 megohms when the central decade of scale is used. Voltage measurement accuracy is ±2% of full scale.

SCALE: standard direct-reading ohmmeter calibration is used; scale is illuminated.

VOLTAGE ON UNKNOWN: does not exceed 106 volts and varies with meter indication.

INPUT RESISTANCE: for voltage measurements input resistance in megohms is indicated by selector switch. On the "infinity" position, resistance is greater than 20,000 megohms.

TEMPERATURE-HUMIDITY EFFECTS: over normal room temperature and humidity ranges, accuracy is substantially independent of either.

DIMENSIONS: 10 x 8 x 5½ inches.

WEIGHT: 8½ pounds, net.

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This megohmmeter is very useful for moderately high resistance measurements such as leakage resistance of cables and insulating samples, locating defective insulation in electrical machinery, and particularly for the determination of moisture content of wood, paper and other products. By means of a panel switch it is convertible to use as a d-c vacuum-tube voltmeter for measurements up to 100 volts, d-c.

The Type 1861-A Megohmmeter is convenient to use, accurate and stable.

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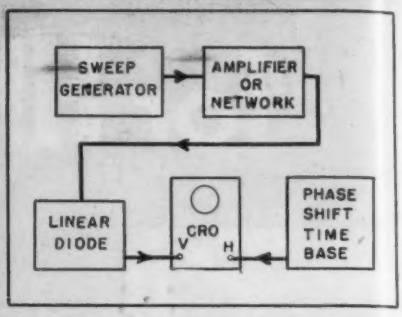

FIG. 2—Conventional circuit for single image alignment

wetted type contacts is recommended to provide the clean baseline and fast action required.

Single Image Alignment

A common arrangement for single image alignment is shown in block form in Fig. 2. Here the sweep generator uses sinusoidal modulation and a sinusoidal time base is used to produce a linear frequency-time pattern. With the modulation and time base voltages in phase, a single image will be seen, assuming no distortion, with the up and down sweeps coinciding at all points. With this arrangement only the a-c component of the rectified wave is viewed and no knowledge of the actual instantaneous voltage is obtained.

The practice of using a sweep-width very wide in comparison to the pass-band of the network under test to obtain two points of assumed zero voltage (F_{max} and F_{min}), may lead to a false picture of the gain-frequency trace. A more accurate picture of the steady-state characteristic of the network under test is obtained by using a narrow sweep-width and the baseline for accurate gain measurements.

Figure 3 shows the blanking unit in block form connected to the common arrangement of Fig. 2. The

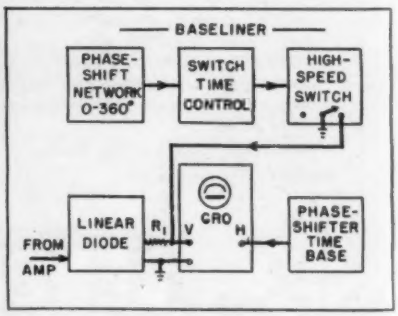

FIG. 3—Addition of the Baseliner provides zero reference trace

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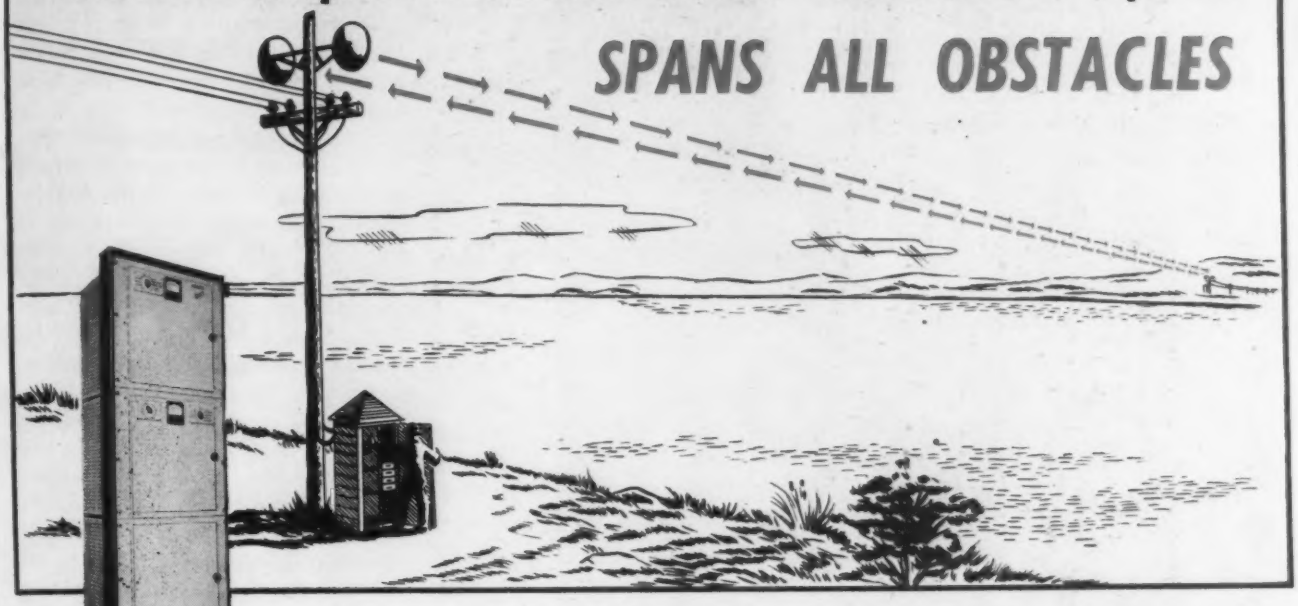

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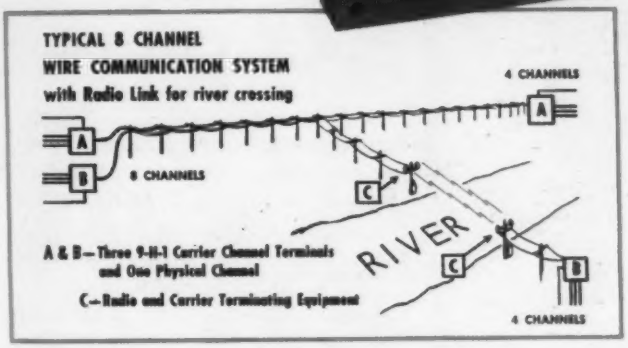

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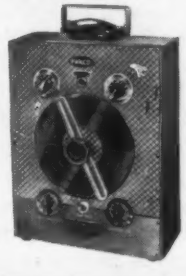

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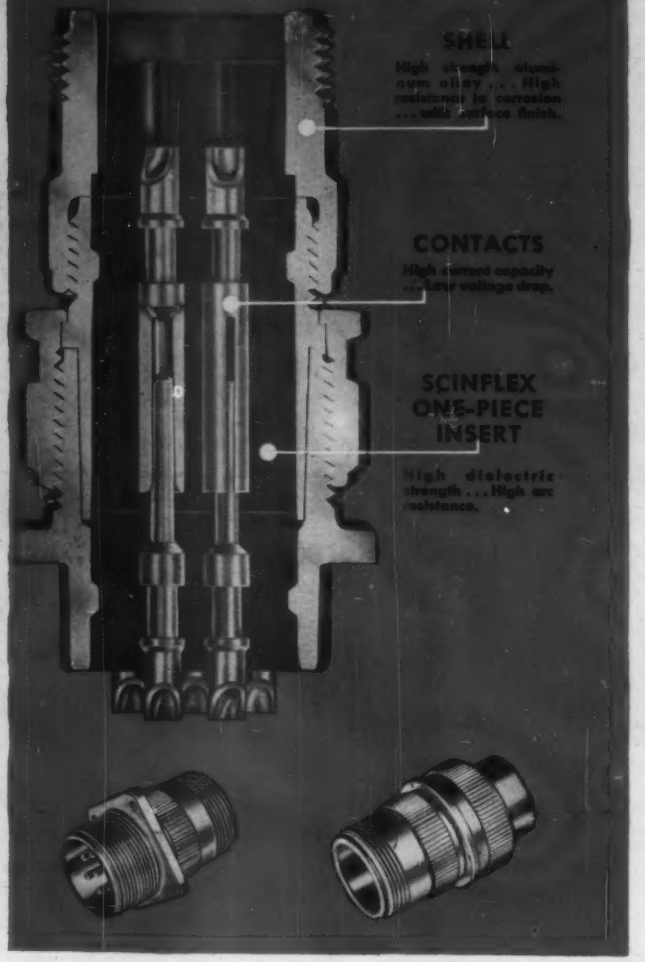

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phase-shift network in the Baseliner is adjusted to make the switch ON time start with either F_{max} or F_{min}. The switch time control is used to adjust the switch ON time to exactly 180 degrees.

With single-image alignment, the procedure is the same as where no blanking is used. With double-image alignment, the blanking is not used until alignment is complete. After alignment is complete the blanking is used and one image disappears, being replaced by the baseline. Absolute gain measurements may then be made.

External input connections allow the use of any switch rate from one to sixty cycles. As the switch contacts are single-pole double-throw, the unit may also be used as a high speed mechanical switch (up to 60 cps) to replace an electronic switch. It is most advantageous where one or more of the signals to be switched has a d-c component that it is desired to preserve.

Reference

(1) Frantz, The Transmission of a Frequency Modulated Wave Through A Network, *Proc. IRE*, Mar. 1946.

PHOTOMETER incorporating a magnetic amplifier has an indicating instrument requiring 5 milliamperes for full-scale deflection instead of a few microamperes as is usually required. The instrument, made by Electro Methods Ltd. (London, England) is thus quite rugged. The photosensitive element can be either a barrier layer or a photoemissive type capable of delivering 0.1 microwatt at 3.5 microamperes to the magnetic amplifier. The indicating instrument requires about 250 microwatts for full-scale deflection, and thus the amplifier provides a power gain of 2,500; it is linear within ±2 percent of full-scale output over its operating range. A 5-percent change in the 50-cps power supply voltage produces only a 1-percent change in output current. Adjustments on the meter enable the zero and sensitivity to be set to standards; the meter is intended for comparison measurements and is calibrated in percent.

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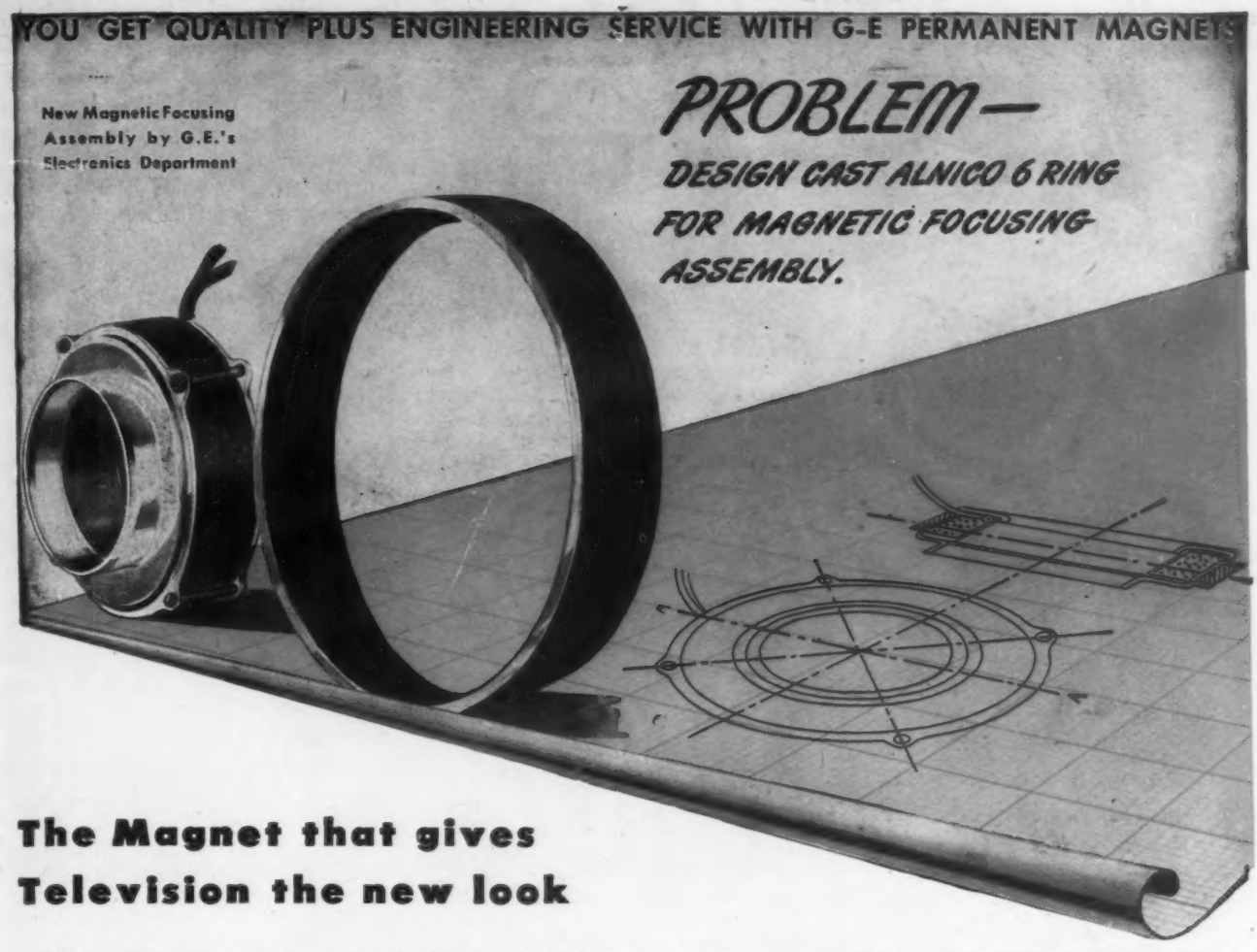
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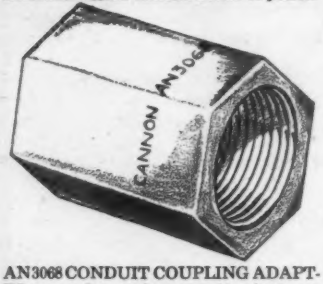

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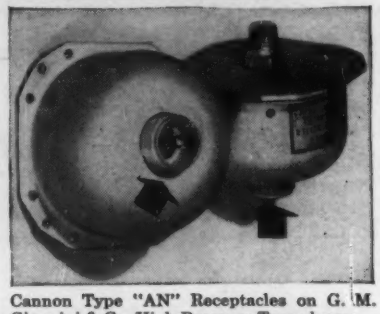

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THE ELECTRON ART

(continued from p 126)

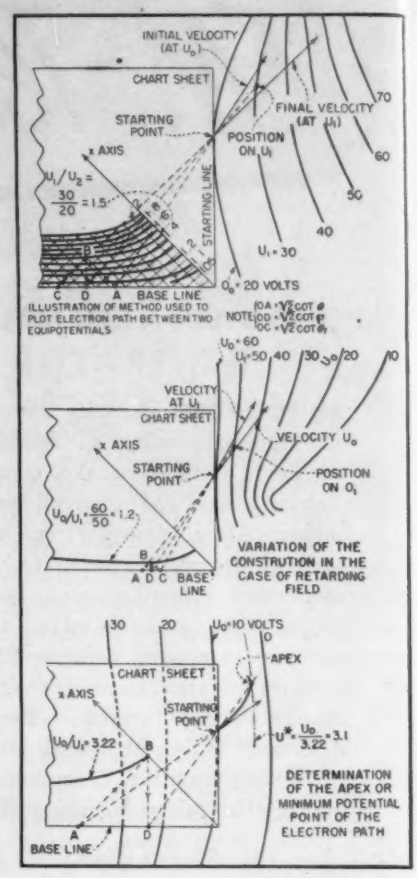
INITIAL VELOCITY (AT U_0)
CHART SHEET
STARTING POINT
x AXIS
FINAL VELOCITY (AT U_1)
POSITION ON U_1
STARTING LINE
$U_1/U_2 = \frac{30}{20} = 1.5$
$U_1 = 30$
$U_0 = 20$ VOLTS
C D A BASE LINE
ILLUSTRATION OF METHOD USED TO PLOT ELECTRON PATH BETWEEN TWO EQUIPOTENTIALS
NOTE
$\overline{OA} = \sqrt{2}\cot\phi$
$\overline{OD} = \sqrt{2}\cot\varphi$
$\overline{OC} = \sqrt{2}\cot\phi_1$
$U_0 = 60$
VELOCITY AT U_1
VELOCITY U_0
POSITION ON O_1
$U_0/U_1 = \frac{60}{50} = 1.2$
VARIATION OF THE CONSTRUTION IN THE CASE OF RETARDING FIELD
A D C BASE LINE
$U_0 = 10$ VOLTS
APEX
$U_0/U_1 = 3.22$
$U^* = \frac{U_0}{3.22} = 3.1$
DETERMINATION OF THE APEX OR MINIMUM POTENTIAL POINT OF THE ELECTRON PATH
BASE LINE

FIG. 3—Chart is used with field map

the $x = y$ line, termed the base line. The coordinates of the chart (parallels of the X and Y axes) cut the base line at 45 deg.

The right-hand edge of the chart is normal to the base line and contains the origin of the chart; this edge is termed the starting line. In operation, the starting line is placed tangent to the equipotential where the electron starts at a point distant $2\frac{1}{2}$ from the origin, marked the starting point; the unit of distance is that used in plotting the chart.

A straight line is projected through the starting point along the direction of the initial velocity, intersecting the base line at point A. The ratio U_1/U_0 or U_0/U_1 whichever is greater is computed. If the field is accelerating ($U_1 > U_0$), the coordinate line from A is followed upward and to the left to the intersection with the corresponding U_1/U_0 line at B, then back to the base line at point C. A straight line is projected from C to the starting point. This line indicates the new direction of the electron as it

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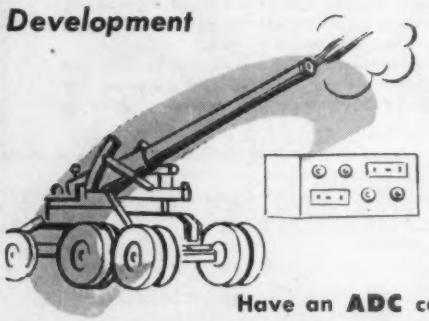

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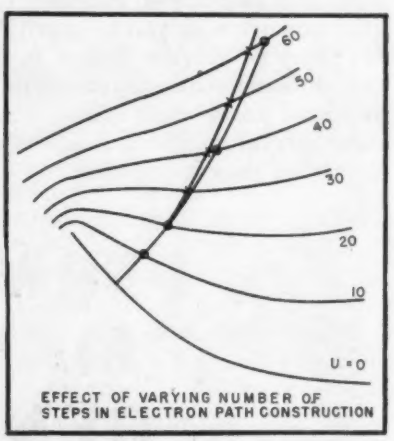
crosses the equipotential U_1. A line drawn on the field map parallel to this line will record this direction.

The point where the electron crosses U_1 is found by locating the midpoint of AC, point D (which can be done by dropping a perpendicular from B to the base line). The straight line projected from D through the starting point to U_1 locates the intersection of U_1 by the electron. The construction is then repeated extending the path to another equipotential U_2, and so on.

If the field is retarding the only difference in the construction is that point B is above and to the right of A, and C is to the right of A instead of to the left. As the electron progresses through a retarding field, there comes a point where the construction cannot be carried out because the electron will not reach the next equipotential, indicated by the fact that the line drawn upward and to the right from A will not intersect the required U_0/U_1 curve. In this case the line is brought to a point on the X axis. The value of U_0 is divided by U_0/U_1 at this point to obtain the minimum potential that the electron will reach.

The equipotential so found contains the apex of the electron trajectory. The point of tangency to this contour is obtained by dropping the normal from the intersection of the X axis to D and drawing a straight line from D to the limiting equipotential through the starting point.

From its apex, the electron curves back to the starting contour U_0. The position and direction of the electron at U_0 is found by inverting



EFFECT OF VARYING NUMBER OF STEPS IN ELECTRON PATH CONSTRUCTION

FIG. 4—More steps give higher accuracy

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the construction whereby the electron was followed initially from U_0 to the apex. For this purpose the position of the chart on the field map must also be inverted because the electron is now passing through equipotentials in the opposite direction. In general, more points are needed near the apex than in other regions to retain the accuracy.

Figure 4 shows an electron path plotted by this method. Two paths have been plotted with different numbers of points to show the change in accuracy. For most purposes the construction with fewer steps will be adequate. If electrons enter the field at an initial emission velocity U_s volts, all contours on the map should be increased by U_s. The direction of emission velocity can be arbitrarily assigned.

Several other graphical methods have been described for plotting electron paths. The simplest and most widely used constructs the path in a succession of arcs of circles.[3] Modifications of this method to overcome the disadvantage on large radii of curvature have been applied to the electron lens[4] and to the cyclotron.[5] Another parabolic method has been described elsewhere.[2] Under the last reference the reader will find a wide survey of other methods.

(1) L. Langmuir and K. Blodgett, Currents limited by space charge between coaxial cylinders, *Physical Review*, p 374, 22, 1923; also p 49, 24, 1924.

(2) V. K. Zworykin and G. A. Morton, "Television", p 73, John Wiley, New York.

(3) H. Salinger, Tracing electron paths in electric fields, ELECTRONICS, p 50, Oct. 1937.

(4) K. Spangenberg and L. M. Field, Some simplified methods for determining the optical characteristics of electron lenses, *Proc. IRE*, p 138, March 1942.

(5) W. E. Parkins and E. C. Crittenden, A graphical method for determining particle trajectories, *Journal of Applied Physics*, p 447, June 1946.

Electronic Circuit has Logarithmic Response

By A. W. NOLLE

Department of Physics
University of Texas
Austin, Texas

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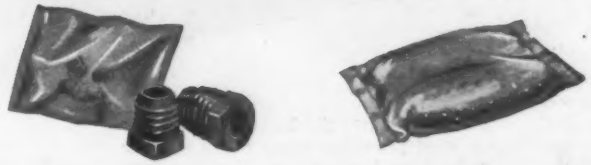

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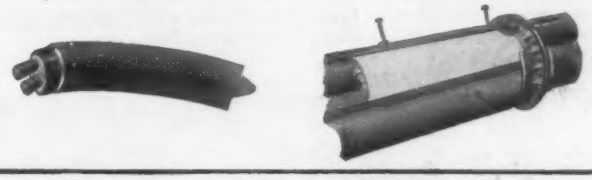

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lated to their inputs, instead of the uniform decibel scale being obtained by modification of the meter movement. The output voltages can then be applied to recording instruments or to oscilloscopes, thus extending the forms in which the logarithmic presentations can be made.

Conventional circuits for this application use nonlinear components such as pentode amplifiers,[1] grid-cathode rectification in triodes,[2] and copper-oxide rectifiers.[3] The circuit described herein uses the exponential characteristics with time of a resistance-capacitance circuit, thus obtaining logarithmic response from an inherent property of the circuit rather than from an approximate characteristic. The exponential response to square-wave exicitation of R-C and R-L-C circuits is familiar and need not be reviewed here.

Basis of Operation

The exponentially decreasing output voltage E_R of, for example, an R-C circuit is $E_R = E_o \exp -t/RC$ where E_o is the initially applied voltage. the time T_K required for the output to decay to an arbitrary value E_K is $T_K = RC(\ln E_o - \ln E_K)$. This equation is the basis for the

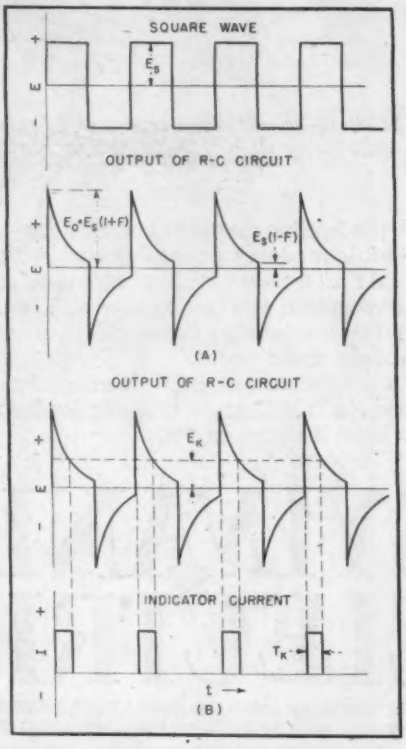

FIG. 1—(A) Response to a repetitive square wave, and (B) sampling action

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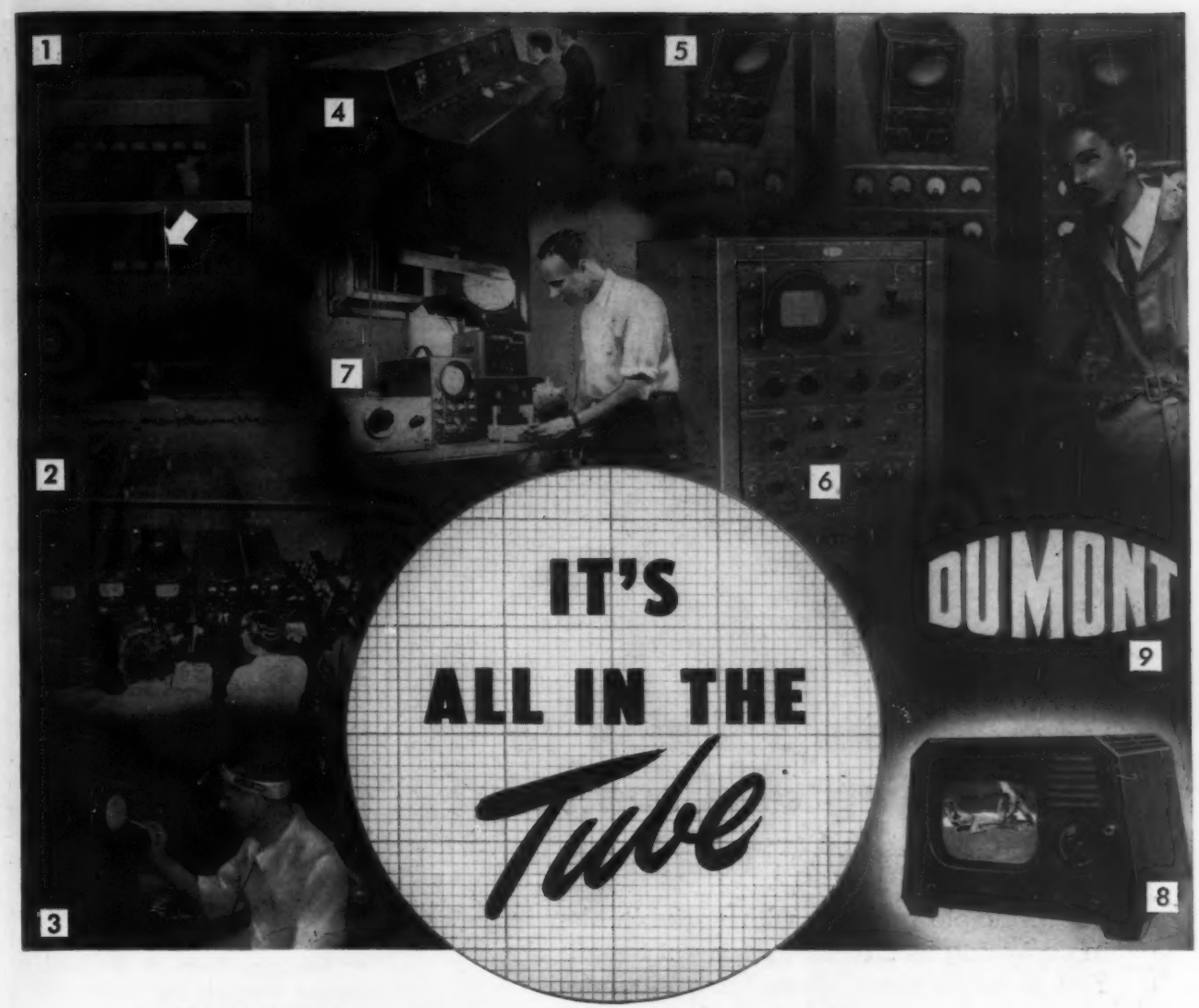

By way of illustration . . . **1.** Du Mont transmitter unit utilizing Du Mont cathode-ray tubes as indicators. **2.** Du Mont television field equipment for picking up remote programs. **3.** Scientific research in medicine, aided by Du Mont oscillography. **4.** Du Mont Television Transmitting Control Console utilizing Du Mont cathode-ray tubes. **5.** Du Mont Type 208-B oscillographs used in nuclear research. **6.** Du Mont Type 280 oscillograph for precision measurements of television waveforms utilizing the Type 5RP-A high-voltage tube. **7** Typical scene in most radio repair shops, where servicemen make their diagnosis with a Du Mont Type 274 oscillograph. **8.** Du Mont Chatham table set with a 12-inch Du Mont picture tube for clear, bright, truly superlative pictures. **9. The symbol of quality cathode-ray tubes—always your best buy**

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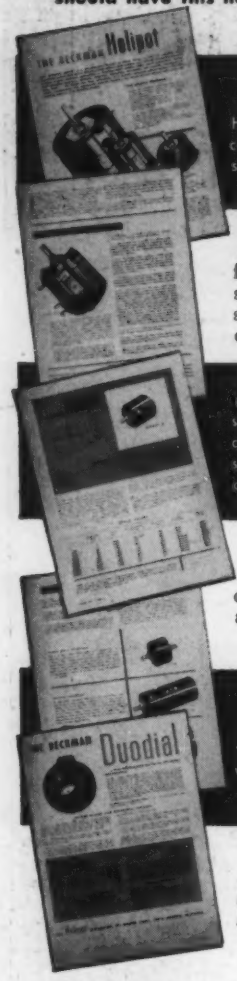

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logarithmic circuit. If either the applied voltage or the arbitrary smaller voltage is made a constant of the apparatus, the partial decay time T_K becomes a linear function of the logarithm of the other voltage. In practice it is simpler to fix E_K and to use E_o as the variable to whose logarithm the instrument responds. The instrument is then designed so that a measurement is made of the time interval for the voltage under test to decay to a standard value. This one measurement is sufficient to give the logarithm of the amplitude of the voltage.

Practical Circuit Design

Because most voltages that are to be measured vary with time and because continuous indications are usually desired, it is necessary to repeat the process continuously. When this is done, a succession of time measurements is delivered to the final indicating device in such electrical form that an averaged indication of its logarithmic level is always presented.

The repetitive action can be produced simply by applying a square wave whose amplitude is proportional to that of the input signal to an R-C or R-L circuit. The output from an R-C circuit is shown in Fig. 1A in relation to an applied square wave of amplitude E_s. Because the capacitor does not charge completely each half cycle, the peak output voltage is $E_o = E_s(1 + F)$ where $F = \tanh(T/4RC)$, T being the period of the applied square wave. At the end of each half cycle the voltage has decayed to $E_s(1 - F)$. In practice the logarithmic response circuit must be designed so that F is nearly equal to unity if differences of the order of 20 db are to be registered. Thus the peak output voltage of the R-C circuit is essentially equal to the peak-to-peak amplitude of the square wave.

The time required for the output voltage of the R-C circuit to decay to the fixed value E_K is T_K. Measurement of T_K will give the correct indication of the logarithmic amplitude of the square wave provided that the peak voltage $E_s(1 + F)$ is (1) greater than the reference voltage E_K but (2) small enough that

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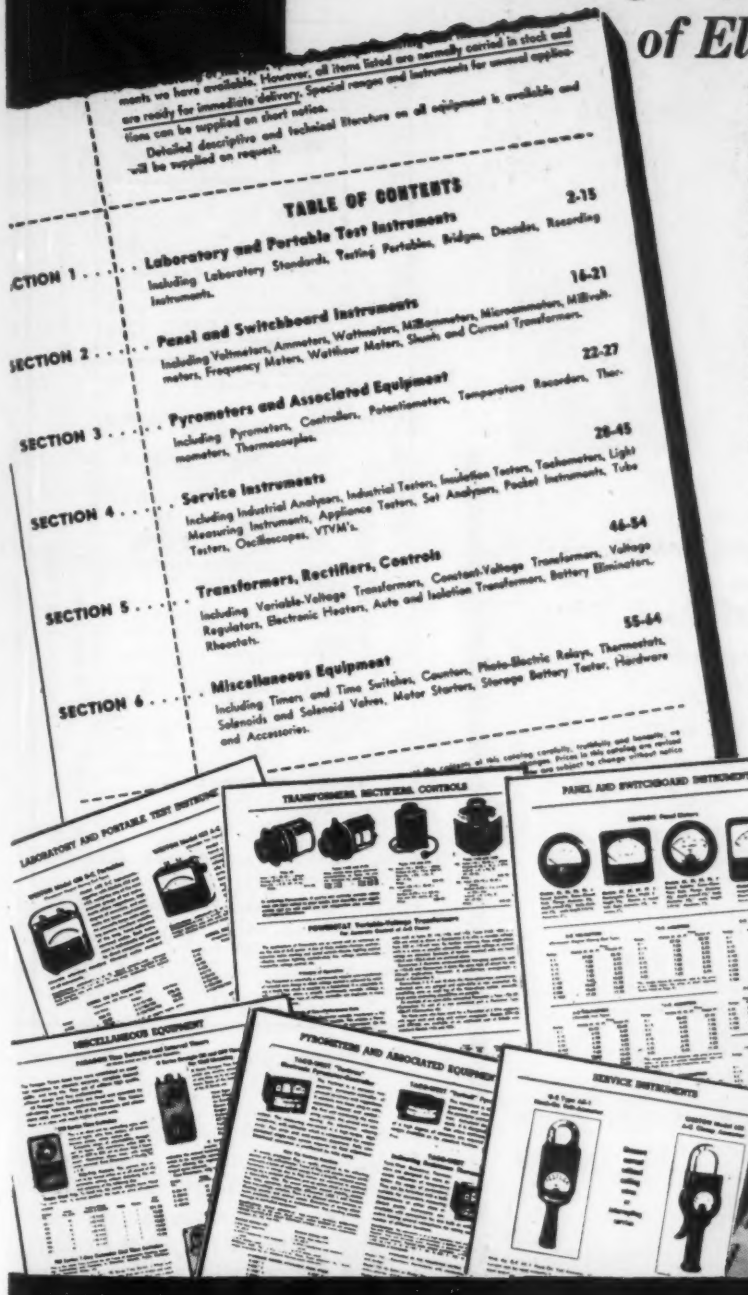
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Here's your simple guide for every type of electrical instrument and control from ammeters to tachometers. No need to check through dozens of catalogs. No need to make telephone calls by the hour. And no need to spend your valuable time shopping from house to house or clogging your office with salesmen. Here within the covers of this catalog are 64 pages jam-packed with over 3,000 instruments and controls...fully described, illustrated and priced. Just to give you an idea of the wide variety of types in this catalog, we list a random dozen:

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MEGGERS	BRIDGES
AUDIO VOLTMETERS	ELECTRONIC COUNTERS
OSCILLATORS	APPLIANCE TESTERS
PYROMETERS	ANALYZERS
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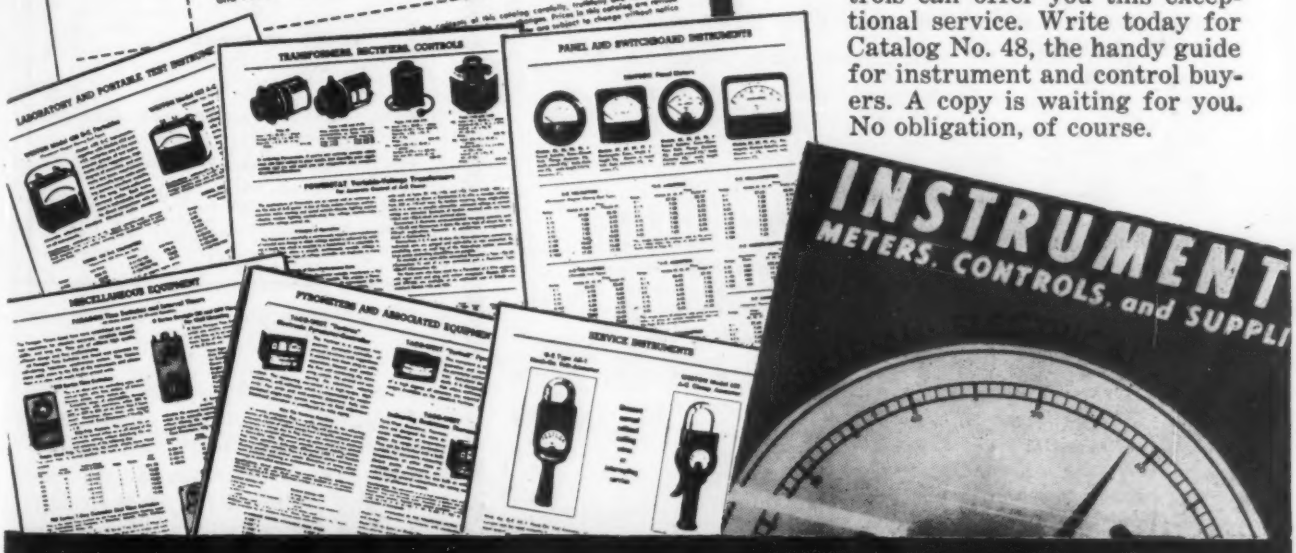

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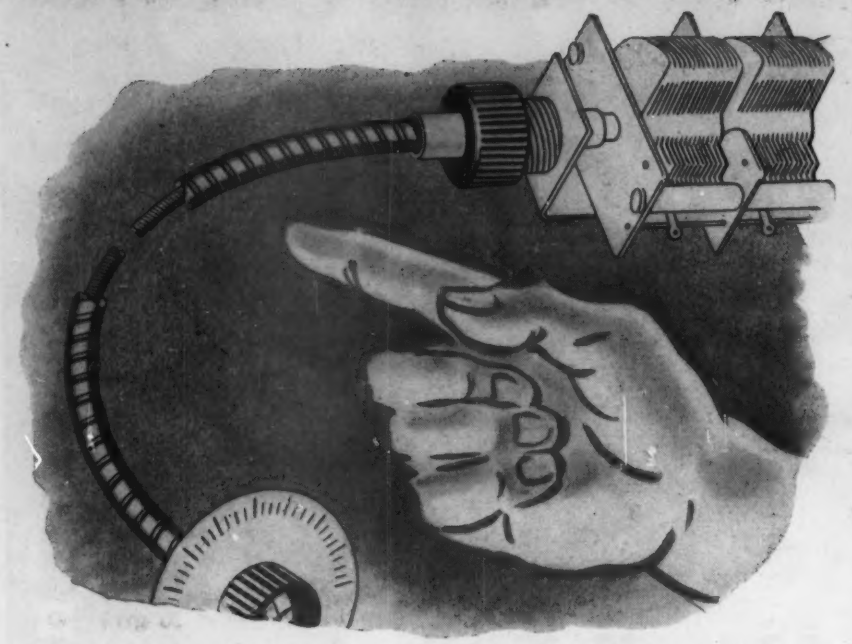

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the interval T_x is less than half a cycle.

Figure 1B shows a method for obtaining a signal indicative of T_x. An indicator circuit is so arranged that current of constant amplitude flows through an indicating instrument, such as a d-c meter, as long as the output of the R-C circuit is greater than E_x. The output of the indicator circuit is thus a pulse train modulated in width in proportion to the logarithm of the amplitude of the initial square wave. The average value of this pulse train produces the proper steady deflection of the indicating instrument. If the calibration of the instrument is to remain fixed, it is essential that the period of the square wave be constant.

There are several other practical considerations: The square-wave generator feeding the R-C circuit must have a constant internal resistance. Full-wave operation can be obtained if the indicating circuit operates on both halves of the square wave, responding to E_x, then to $-E_x$. The meter deflection per db can readily be controlled by varying the resistance of the R-C circuit. The absolute level of the meter scale can be controlled by the amplification of the input signal and by the magnitude of the bucking current through the meter, which should be large enough that, in the absence of signal input, the indicating element will be off scale so as to avoid ambiguity.

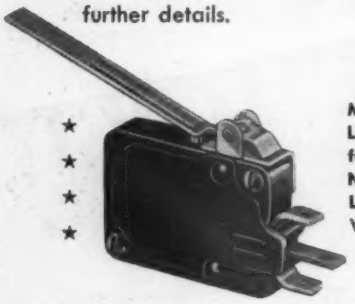
A Specific Circuit

Figure 2 shows the diagram of a specific circuit which has a logarithmic range of more than 20 db. This circuit is designed for measuring alternating voltages and therefore is provided with an a-c amplifier stage and a balanced voltage-doubler rectifier. This rectifier converts the signal into direct voltages at A and B that are positive and negative respectively by equal amounts as compared to the average potential at D.

A limiting amplifier, excited by the high voltage from the power transformer, develops a square wave at D whose peak-to-peak amplitude closely equals the voltage difference between A and B because of the action of the limiting diodes. A variable bias current is obtained

ACRO *Model M*
SNAP ACTION SWITCH

Here's the sturdy little fellow you've been looking for—it lets you design for compactness. Thinnest switch made, it is no thicker than an ordinary match book and only slightly larger than a postage stamp—yet it delivers long, dependable service with the utmost accuracy. ACRO'S **exclusive** rolling spring action is the key to its superlative performance—the reason why it's the choice of hundreds of manufacturers. Code 2MD3-1A approved by Air Materiel Command. Write for further details.



Model M fitted with No. A-18 Leaf Actuator Bracket. Also furnished with Roller Leaf, No. A-18M. Underwriters' Lab., Inc. Insp. 10 Amps, 125 V., 5 Amps, 250 V., A. C.

Coin Model M with No. A-22 Wire Leaf Actuator for coin operated machines. Length and form of wire can be made to suit job. Underwriters' Lab., Inc. Insp. 3 Amps. 125 V., 3 Amps, 250 V., A. C.

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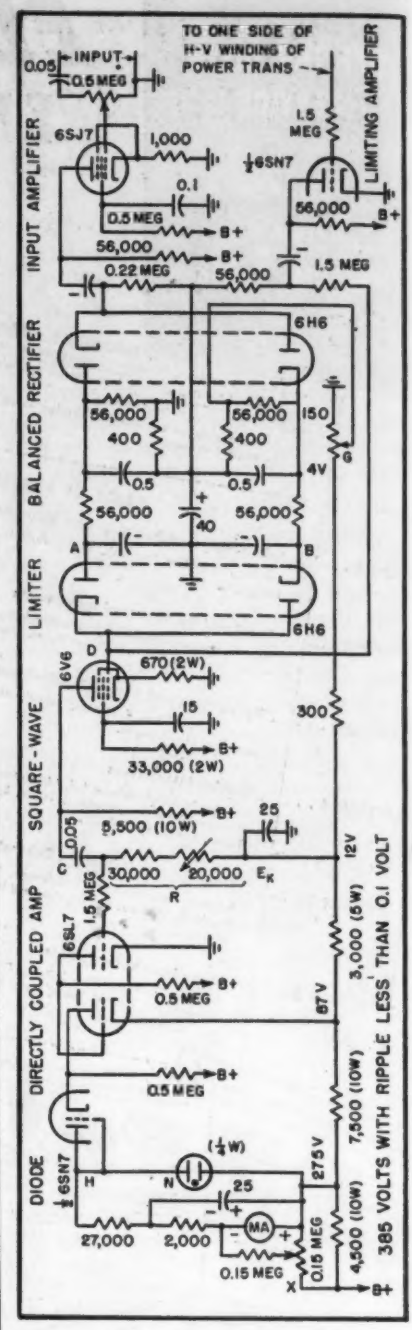

FIG. 2—Circuit diagram of instrument having full-scale response of 20 db

from *G* to assure that both the rectifying and the limiting diodes operate only within their linear regions. This bias is desirable to avoid operation of the diodes in their low-current regions where there is considerable variation of plate resistance, thus improving the linearity of the circuit at low levels. The rectifier-limiter circuit is adjusted so that changes of input level produce very little variation of direct voltage level at *D*.

The portion of the circuit de-

PLASTICON CAPACITORS

HI VOLT POWER SUPPLIES

Designed to transform 118 VAC to high voltage—low current DC for use in radiation counters, oscilloscopes, dust precipitators, projection television sets, spectographic analysers, photoflash equipment, etc. Hi Volt Power Supplies are sch-contined in nermeticaly sealed steel containers.

HIVOLT

Cat. No.	VDC	Dimensions	Your Cost
PS-1	2400	3¼x3¾x5½"	$11.14
PS-2	2400	3¼x3¾x5½"	15.14
PS-5	5000	4¼x3¾x6½"	38.22
PS-10	10000	4¼x3¾x8"	58.80
PS-30	30000	7x7x7"	147.00

PHOTOFLASH CAPACITORS

For the best in photoflash capacitors, specify PLASTICONS for faster discharge and more light. Type AOCOE are the lightest photoflash capacitors made, more flexible to use, safer and more economical than single high capacitance large block.

PHOTO FLASH

Cat. No.	Watt Sec.	Pk. Chg V.	Dimensions	Your Cost
AOCOE22C3	7.6	2250	4x2x1¼"	$2.92
AOCOE3M2	9	3000	4x2x1¼"	3.00
AOCOE4M1.5	12	4000	4x2x1¼"	3.20
AOCOE55C1	15.1	5500	4x2x1¼"	3.60
AOCE4M12	100	4000	4½x4¼x3¾	27.17
AOCE4M24	200	4000	8x4¼x3¾"	38.81

PLASTICONS

By the use of synthetic plastic film dielectrics, PLASTICONS can be made smaller, lighter, more efficient and more economical than older types of capacitors made with paper and mica insulation. Plasticon films are chemically purer and more uniform. Plasticon capacitors have a longer life and can operate under more severe conditions.

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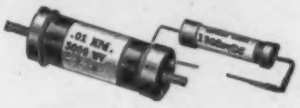
Taking advantage of the wide variety of plastic film dielectric characteristics, Plasticons are engineered to meet many special applications. We can furnish capacitors for 200°C for pulse network duty; close tolerances; ultra high resistance. Send us your specifications.

GLASSMIKES ASG



Type ASG are Plasticon A dielectric-silicone fluid impregnated capacitor elements in hermetically sealed glass tubes. Temperature range — 60° C to + 125° C. The smallest and lightest high voltage capacitors made. Type ASG are ideal for DC and low frequency AC applications

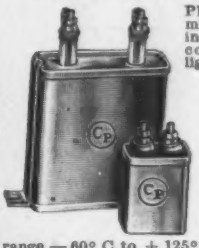
Cat. No.	Cap. Mfd.	Volts D.C.	Dimensions	Your Cost
ASG 1	.01	600	19/64x1⅛"	$ .88
ASG 2	.02	600	19/64x1⅛"	.94
ASG 3	.05	600	19/64x1⅛"	1.03
ASG 4	.1	600	¾x1⅛"	1.15
ASG 5	.25	600	39/64x2⅛"	1.32
ASG 6	.5	600	1⅜x2⅜"	1.53
ASG 7	.005	1,000	19/64x1⅛"	.88
ASG 8	.01	1,000	19/64x1⅛"	.94
ASG 9	.02	1,000	19/64x1⅛"	1.00
ASG 10	.05	1,000	¾x1⅛"	1.09
ASG 11	.1	1,000	¾x2⅛"	1.26
ASG 12	.25	1,000	39/64x2⅛"	1.47
ASG 13	.002	2,000	19/64x1⅛"	1.12
ASG 14	.005	2,000	19/64x1⅛"	1.21
ASG 15	.01	2,000	19/64x1⅛"	1.32
ASG 16	.02	2,000	19/64x1⅛"	1.47
ASG 17	.05	2,000	¾x1⅜"	1.66
ASG 18	.1	2,000	39/64x2¼"	1.88
ASG 19	.25	2,000	1⅜x2¾"	2.18
ASG 20	.001	3,000	19/64x1⅛"	3.03
ASG 21	.002	3,000	19/64x1⅛"	3.09
ASG 22	.005	3,000	19/64x1⅛"	3.18
ASG 23	.01	3,000	19/64x1⅛"	3.28
ASG 24	.02	3,000	¾x1⅜"	3.44
ASG 25	.05	3,000	39/64x2¼"	3.62
ASG 26	.1	3,000	1⅜x2¾"	3.92
ASG 27	.001	5,000	19/64x1⅛"	3.82
ASG 28	.002	5,000	19/64x1⅛"	3.94
ASG 29	.005	5,000	19/64x1⅛"	4.09
ASG 30	.01	5,000	¾x1⅜"	4.26
ASG 31	.02	5,000	¾x2¼"	4.50
ASG 32	.05	5,000	1⅜x2¾"	4.79
ASG 33	.1	5,000	1⅜x3½"	5.35
ASG 34	.001	7,500	19/64x1⅛"	4.12
ASG 35	.002	7,500	19/64x1⅛"	4.26
ASG 36	.005	7,500	¾x1⅜"	4.44
ASG 37	.01	7,500	¾x2¼"	4.79
ASG 38	.02	7,500	39/64x2¼"	5.44
ASG 39	.05	7,500	1⅜x2¾"	6.76
ASG 40	.0005	10,000	19/64x1⅛"	4.28
ASG 41	.001	10,000	19/64x1⅛"	4.41
ASG 42	.002	10,000	19/64x1⅛"	4.59
ASG 43	.005	10,000	¾x1⅜"	5.29
ASG 44	.01	10,000	39/64x2¼"	6.17
ASG 45	.02	10,000	1⅜x2¾"	7.35
ASG 46	.03	10,000	1⅜x3½"	8.82
ASG 60	.06	10,000	1⅜x3½"	10.29
ASG 47	.0005	15,000	39/64x2¼"	8.53
ASG 48	.001	15,000	39/64x2¼"	8.70
ASG 49	.002	15,000	1⅜x2¾"	9.12
ASG 50	.0005	20,000	1⅜x3½"	11.47
ASG 51	.001	20,000	1⅜x3½"	12.07
ASG 52	.0005	30,000	1⅜x3½"	13.24

RF GLASSMIKES

Plasticon L film-silicone fluid impregnant in Glassmike style case. Type LSG has Q of 2500 to 5000. Rated at 3500 WV—7500 V Test. Lower losses, more easily mounted, smaller and more economical than mica capacitors.

Cat. No.	Cap. Mfd.	Dimensions OD Length	Your Cost
LSG500	.00005	19/64x1⅛"	$.88
LSG101	.0001	19/64x1⅛"	.88
LSG251	.00025	19/64x1⅛"	.88
LSG501	.0005	19/64x1⅛"	.88
LSG102	.001	19/64x1⅛"	1.00
LSG202	.002	¾x1⅛"	1.44
LSG502	.005	¾x1⅜"	2.06
LSG602	.006	39/64x1⅜"	2.20
LSG103	.01	39/64x1¾"	2.49

INDUSTRIAL and TRANSMITTING



Plasticon A element; mineral oil impregnated in sturdy lead coated steel containers. Smaller, lighter and more economical than paper capacitors. Temperature range —40°C to +105°C. Type AOC-rectangular; Type AOCO-flattened oval.

Type ASC and ASCO (not listed) have Plasticon A element, silicone impregnated. Same dimensions as corresponding AO types. Temperature range — 60° C to + 125° C; greater capacitance stability. Prices on application.

DC RECTANGULARS

Cat. No.	Cap. Mfd.	Volts DC	Dimensions	Your Cost
AOC6C1	1.0	600	2⅛ 1¾ 1"	$2.19
AOC6C2	2.0	600	2⅛ 1¾ 1"	2.65
AOC6C4	4.0	600	3½ 2½ 1⅝"	3.30
AOC6C8	8.0	600	4 3⅜ 1¾"	4.98
AOC6C10	10.0	600	4⅛ 3⅜ 1¾"	5.80
AOCIM1	1.0	1,000	2⅜ 1⅜ 1"	2.37
AOCIM2	2.0	1,000	4 1⅜ 1"	2.59
AOCIM4	4.0	1,000	4 2½ 1⅝"	3.86
AOCIM8	8.0	1,000	4⅛ 3¼ 1¾"	5.43
AOCIM10	10.0	1,000	4⅛ 3¼ 1¾"	6.27
AOC2MO5	0.5	2,000	2⅛ 1¾ 1"	2.87
AOC2M1	1.0	2,000	3½ 1¾ 1"	3.47
AOC2M2	2.0	2,000	3½ 2½ 1⅝"	4.02
AOC2M4	4.0	2,000	3½ 3¾ 1¾"	5.43
AOC3M1	1.0	3,000	4 2½ 1⅝"	7.12
AOC3M2	2.0	3,000	4 3¾ 1¾"	9.05
AOC3M4	4.0	3,000	4⅛ 3¾ 2¼"	12.52
AOC4M1	1.0	4,000	4 3¾ 1¾"	16.17
AOC4M2	2.0	4,000	4 3¾ 1¾"	19.40
AOC4M4	4.0	4,000	4 3¾ 4⅛"	29.66
AOC5M1	1.0	5,000	4 3¾ 1¾"	19.40
AOC5M2	2.0	5,000	3½ 3¾ 4⅛"	24.70
AOC75C1	1.0	7,500	3½ 3¾ 4⅛"	29.11
AOC10M1	1.0	10,000	4 3¾ 4⅛"	51.74

DC OVALS

Cat. No.	Cap Mfd.	Volts D.C.	Dimensions	Your Cost
AOCO6C2	2.0	600	2⅜ 2 1¼"	$2.59
AOCO6C4	4.0	600	4 2 1¼"	3.11
AOCO1M1	1.0	1,000	2¾ 2 1¼"	2.26
AOCO1M2	2.0	1,000	3½ 2 1¼"	3.04
AOCO3MO1	0.1	3,000	2¾ 2 1¼"	4.46
AOCO5MO1	0.1	5,000	2¾ 2 1¼"	8.28
AOCO5MO25	0.25	5,000	3½ 2 1¼"	9.05
AOCO5MO5	0.5	5,000	4¾ 2 1¼"	10.68
AOCO8MOO5	0.05	8,000	2¾ 2 1¼"	8.93
AOCO8MO1	0.1	8,000	3½ 2 1¼"	9.83
AOCO10MOO5	0.05	10,000	3½ 2 1¼"	11.32

LABORATORY CAPACITORS

Type LAG (Glassmike style) and Type LAC (Rectangular can) have the lowest dielectric absorption of any capacitor made. Residual charge is .01 — .02%. Dissipation factor at 1 MC is .0002 to .0003. Capacitance and Q is constant from DC to 100 KC. Resistance averages one million megohms per microfarad. Standard capacitance tolerance is ± 5%. Type LA units are used for timing and integrating circuits.

Cat. No.	Cap. Mfd.	Dimensions	Your Cost
LAG101	.0001	19/64x1⅛"	$1.76
LAG201	.0002	19/64x1⅛"	1.76
LAG501	.0005	19/64x1⅛"	1.76
LAG102	.001	19/64x1⅛"	1.76
LAG202	.002	19/64x1⅛"	2.06
LAG502	.005	¾x1¾"	2.88
LAG103	.01	¾x1¾"	3.94
LAG203	.02	¾x2¼"	5.12
LAG503	.05	39/64x2¼"	6.17
LAC104	.1	2¼x1⅜x1"	9.23
LAC204	.2	2¼x2½x1⅝"	9.82
LAC504	.5	4x2½x1⅝"	12.35
LAC105	1.	4x3¼x1⅛"	18.87
LAC205	2.	4x3¼x2¼"	30.16
LAC505	5.	6x3¾x4⅛"	57.98

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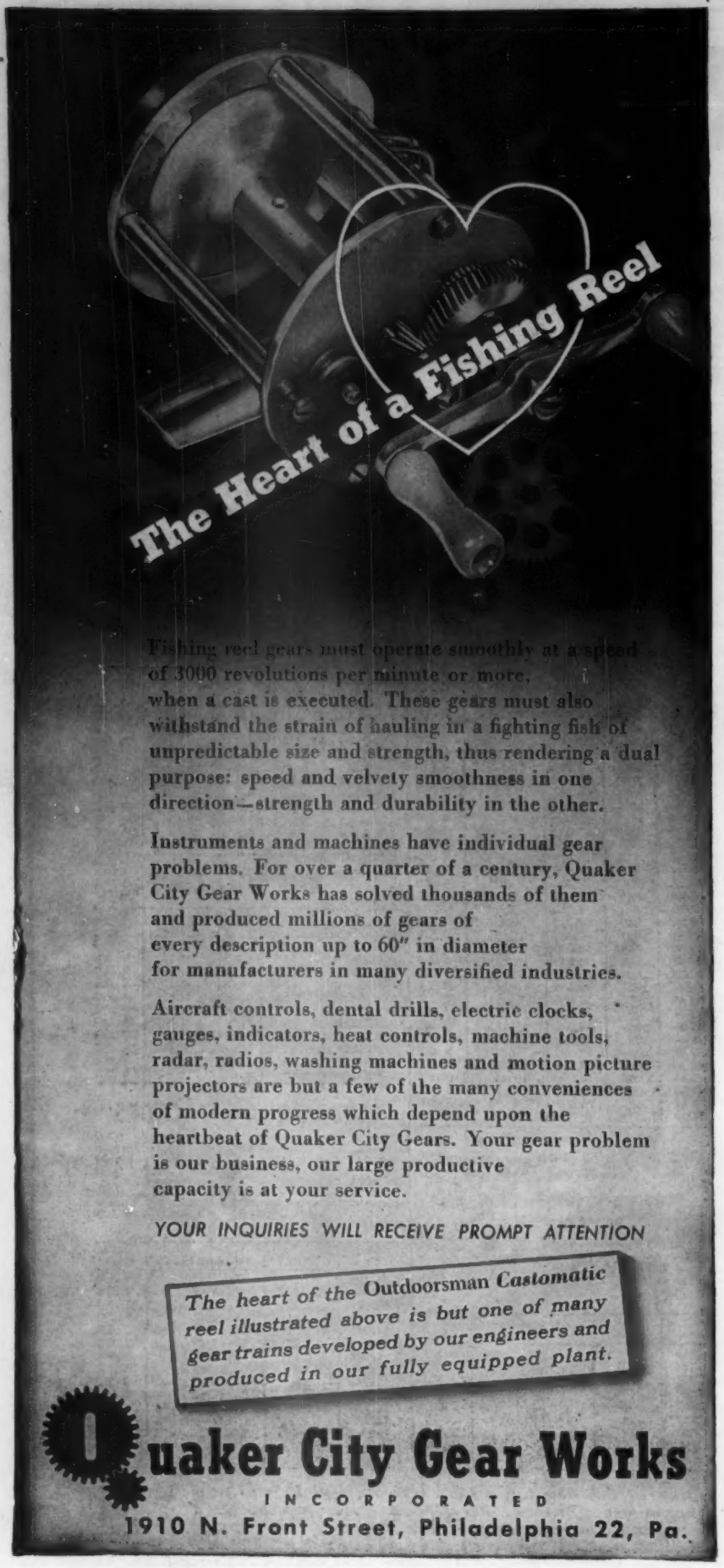

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YOUR INQUIRIES WILL RECEIVE PROMPT ATTENTION

The heart of the Outdoorsman *Castomatic reel illustrated above is but one of many gear trains developed by our engineers and produced in our fully equipped plant.*

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scribed thus far generates a constant-frequency (60 cps) square wave whose amplitude is proportional to that of the input signal. This square wave is amplified and applied to the R-C circuit. The effective resistance of this circuit includes the generator impedance contributed by the amplifier stage. Resistance R is adjustable so that the desired scale factor can be obtained on the indicating instrument. The circuit is terminated on a low-impedance bleeder that provides the reference E_K. The values shown produce a 20-db scale on a 1-ma meter; a 30-db scale can be obtained by reducing the 30,000-ohm fixed resistor to 15,000 ohms and adjusting E_K to about 5 volts.

The output of the R-C circuit feeds a two-stage directly coupled amplifier. In the absence of signal the reference voltage E_K at the grid of the first stage acts to cut off the second stage. The plate of the second stage is then at a higher potential than the indicating instrument circuit at H and no current passes the diode. When signal is present, the second stage of the d-c amplifier conducts whenever the output of the R-C circuit is less than its average value by at least E_K. During these intervals, constant current passes through the meter M. Neon bulb N regulates this constant current. Control X determines the magnitude of reverse meter current employed to place the zero off scale; it may be used as a fine adjustment to set the end of the scale to correspond to a specified input voltage.

Response of the Meter

The frequency response of the instrument and its absolute sensitivity within gross limits are determined by the input amplifier, which is conventional. The full-scale indication of the instrument as shown in the circuit diagram corresponds to an input of about 3 rms volts.

With the instrument adjusted for a 30-db scale, it is accurate within 0.1 db over the top 20 db. If the linearity control is properly adjusted, this accuracy can be extended over the full-scale range. Thus, while it is possible to secure substantially ideal performance over a 30-db range, this result is

only obtained by careful correction of the rectifier and limiter diodes. Therefore the circuit is shown for a 20-db scale for which critical adjustments are unnecessary. The sensitivity of the instrument to line voltage changes is 0.07 db per volt, which represents a uniform scale drift.

Design Limitations

The serious source of error is the rectifier-limiter circuit. The portion of the meter following the rectifier-limiter circuit of Fig. 2 is accurate within ±0.2 db over a 30-db range.

If it were required to redesign the meter for a 30-db range, an input stage having a larger output capability than the 6SJ7 would be necessary so that the rectifiers and limiters could be operated farther into their linear ranges. If this were done, the square wave would have to be attenuated before going to the grid of the 6V6 power stage.

The maximum useful range of the logarithmic circuit, which begins after the limiter diodes, is determined by the finite on-off sensitivity of the d-c amplifier. This sensitivity is of the order of 0.1 volt, and must be small compared to E_K in order that sharply defined pulses be produced. Thus there is a lower limit to E_K of about 3 volts. If the working range of the circuit is to be as much as 40 db, the peak-to-peak undistorted output of the square-wave amplifier must be greater than 3 volts by the 40 db plus a safety margin of about 3 db, or 400 volts peak-to-peak. Because of this requirement, a reasonably portable instrument is limited to about 30 db full scale.

The R-C filters between the rectifiers and the limiters are important to prevent slow periodic variations of the instrument indication at certain input frequencies. When the input frequency is nearly a multiple of the 60-cps square wave, ripple in the rectifier output is sampled in stroboscopic fashion in the limiting process. Thus a 10-percent ripple component in the rectifier output could produce a cyclic 1-db variation in the instrument indication.

These R-C filters are the chief factors in limiting the speed of response of the instrument; the values for them shown in Fig. 2 are commensurate with the mechanical

CURRENT CONVERSION

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For Inverting D. C. to A. C. . . .

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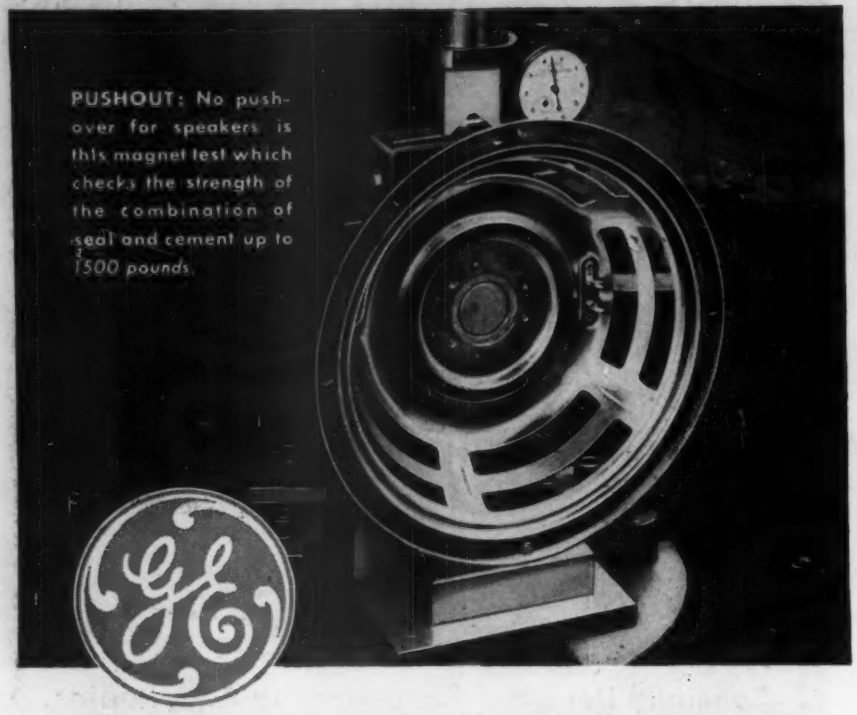
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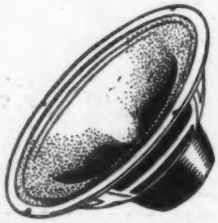

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performance of usual milliammeters. If more rapid response were desired for operation of a high-speed recorder or for presentation of the results on an oscilloscope, it would be necessary to redesign the instrument for operation at a higher square-wave frequency. This change, although increasing the circuit complexity, would produce a faster response by providing more rapid sampling and by permitting reduction of the time constants of the R-C filters.

Acknowledgements

The author is pleased to acknowledge the cooperation of the Ordnance Research Laboratory of the Pennsylvania State College, with whose facilities a preliminary test of the principle of the logarithmic circuit described above was made, and of the Electrodyne Company of Boston, to whom development rights have been assigned.

(1) S. Ballantine, ELECTRONICS, p 472, 1931, and *Jour. Acous. Soc. Am*, p 10, 5, 1933; also F. V. Hunt, *RSI*, p 672, 4, 1933; W. Holle and E. Lubcke, *Hochfrequenztechn. u. Elektroakustik*, p 41, 48, 1936; M. Nuovo, *Ricerca Scientifica*, p 522, 2, 1937.

(2) M. Lambrey, *Comptes Rendus*, p 1023, 201, 1934, and also M. Nuovo, *Alta Frequenza*, p 206, 8, 1939.

(3) H. G. Thilo, *Zeits. f. Techn. Physik.*, p 558, 17, No. 12, 1936.

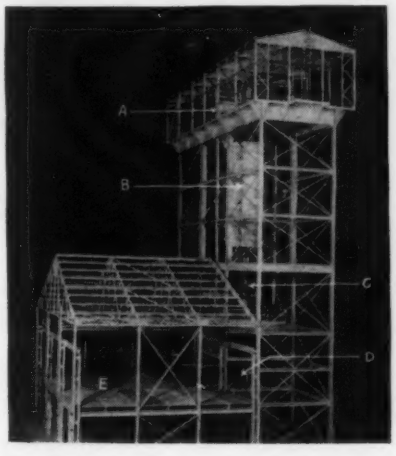
SURVEY OF NEW TECHNIQUES

PROPAGATION MEASUREMENTS conducted at the National Bureau of Standards under the direction of K. A. Norton indicate that atmospheric ducts may increase the range beyond line of sight of f-m broadcasting stations operating in the 88 to 108 mc band. The effect is most pronounced in the early morning and reaches a maximum during the summer months. (Ed. Note: Listeners have begun reporting reception of distant f-m stations now that the summer is here.) The increased transmission is caused by changes in refractive index in the region from 10,000 to 20,000 feet of air strata of different temperatures and hence different densities. The measurements also indicate that increased transmitter antenna height is more effective in increasing range than increased power. For rural areas, receivers that definitely limit with signals of five

microvolts per meter will not be affected by natural noise, except possibly strong local lightning. For the most part fading at great distances is caused by multipath effects.

THICKNESS of cigarette paper can be controlled to within 0.2 micron (0.2×10^{-6} meter) by a beat-frequency capacitance meter. The method, being applied in French factories manufacturing paper having a thickness of about 0.001 millimeter, is based on developments described by J. Coulon in his doctor's thesis at the Faculte des Sciences de l'Uinversite de Toulouse, France. The thesis reports methods of stabilizing the frequency of crystal oscillators.

LINEAR electrostatic accelerator, designed to yield positive ions with energies up to 12 mev, will be built at the University of California Los Alamos Scientific Lab. Although other types of accelerators capable of higher energies are operating or under construction, there is need in nuclear technology for precise measurements within the range for which this new machine is designed; beam energies will be controllable to a precision of one-tenth of a percent (orbital accelerators are accurate to only about two percent). The flexibility of the energy controls will permit experimenters to select particles and target materials to produce monoenergetic neu-



Housing for accelerator accommodates 150-ton crane (A) to lift pressurized generator (B) so that vital parts can be adjusted, stack of annular steel plates and insulators (C) inside which beam is formed and accelerated toward deflecting magnet (D) that directs beam into target room (E) where nuclear reactions will be produced

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SHAPE If your electronisms require metal-shielded wire or seamless tubing for pointers, Bourdon gauges, antennas or other uses—Precision Tubing is formed or flattened to the shape you specify with Nth degree accuracy . . . ready for immediate application.
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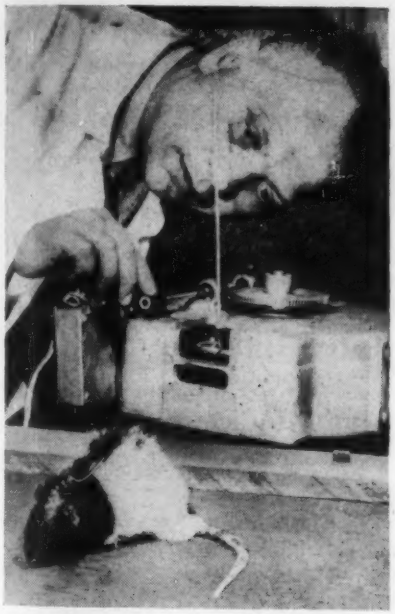
tron beams of any energy from 0.03 to 30 mev. The accelerator is basically a pressurized version, as developed by R. C. Herb of the University of Wisconsin, of the Van de Graaf generator. The building in which it will be housed is to be located at the base of a cliff, which will give lateral bracing to the tower and serve as a radiation shield for the control room and general laboratory that will be located atop the nearby mesa.

LABORATORY RATS carrying miniature radio receivers are being used at the University of California, Los Angeles, by Dr. J. A. Gengerelli. The object is to study learning and retention traits of the rats. The rats are enclosed in mazes through which they can run freely. By means of a radio transmitter tuned to the frequencies of the rats' receivers, electrical impulses can be



Dr. Gengerelli adjusts transmitter that sends impulses to tiny crystal rectifier placed under skin covering rat's skull. Note antenna wire projecting above rat

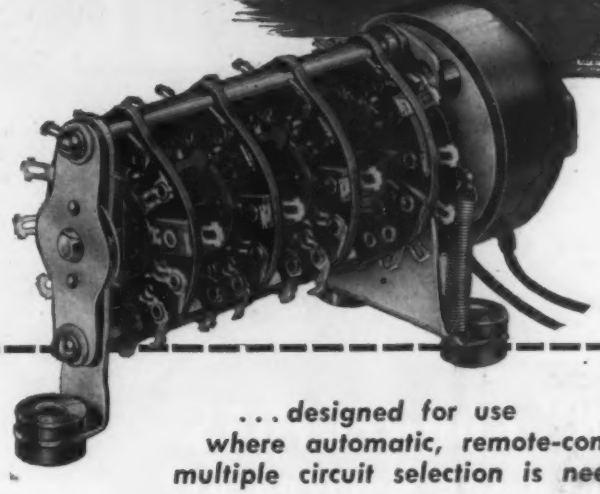
delivered to their brains. In this way traits that might be influenced by electrical shock can be studied without the hindrance of long wires connected to the rats.

A GROUP of cemeteries in Chicago will use a 160-mc Motorola central station and a radio dispatcher to help in the maintenance of extensive grounds and the smooth handling of funeral processions.

LEDEX

CIRCUIT SELECTOR SWITCH

✓ REMOTE CONTROL
✓ ROTARY SOLENOID OPERATED



. . . designed for use where automatic, remote-controlled, multiple circuit selection is needed.

The model illustrated is a six pole, six position circuit selector with standard mounting. Ledex Circuit Selector Switches are also available from stock in the following models; three pole twelve position, and six pole six position, all with either standard or panel mounting. Where quantity requirements justify, *special selectors* for specific applications will be engineered and priced by quotation.

The rotors of Ledex Circuit Selector Switches are powered by Ledex Rotary Solenoids. This compact, powerful solenoid is converted to a rapidly oscillating motor by means of a commutating switch and return spring. Provisions are made to operate Ledex Circuit Selector Switches from any standard power source.

Precision manufacture to exacting specifications and individual operating tests are your assurance of dependable, long-life service under severe operating conditions.

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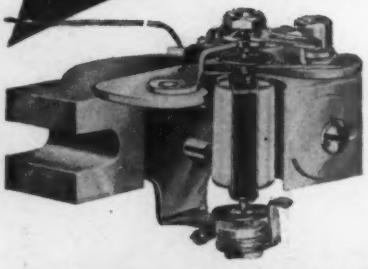

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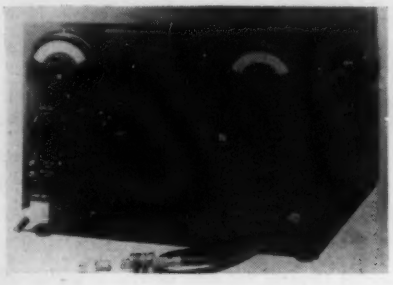
due to line voltage fluctuations. Readings are obtained merely by the operation of an on-off toggle switch, no previous current adjustments or calibration being required.

Signal Generator

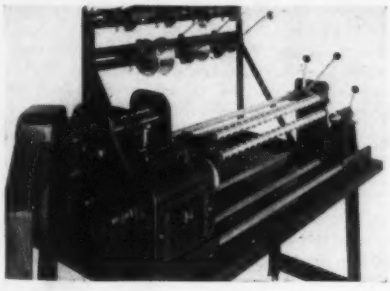
THE ROLLIN CO., 2070 N. Fair Oaks Ave., Pasadena 3, Calif. Model 30 power-type standard signal generator has 6 watts nominal r-f output and 50-ohm impedance with a 160-db range of attenuation and c-w, a-m or pulse operation. It can be



tuned from 40 to 400 mc and has a spiral dial scale equivalent to 4 feet in length.

Coil-Winding Machine

ASSOCIATED PRODUCTION CO., 2655 W. 19th St., Chicago 8, Ill., announces new improvements in a



coil-winding machine that permits almost micrometer adjustment of guide roller travel through positive electric limit switches. The machine winds coils of all types in 16 gage to 42 gage wire. Maximum arbor space is 36 inches.

Mobile Dynamotor

GOTHARD MFG. CO., 2110 Clear Lake Ave., Springfield, Ill. Model GP-26 dynamotor was designed chiefly for mobile transmitters but is suited to

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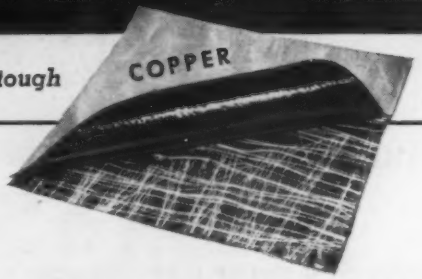

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The success of COPPER ARMORED SISALKRAFT for shielding during the past decade suggests that you might find this reinforced "electro sheet copper" product practical for rooms and large enclosures or equipment requiring electrostatic shielding.

SISALKRAFT engineers do not presume to be authorities on this complex subject. We shall be glad to cooperate, however, on the basis of experience gained in such installations as:

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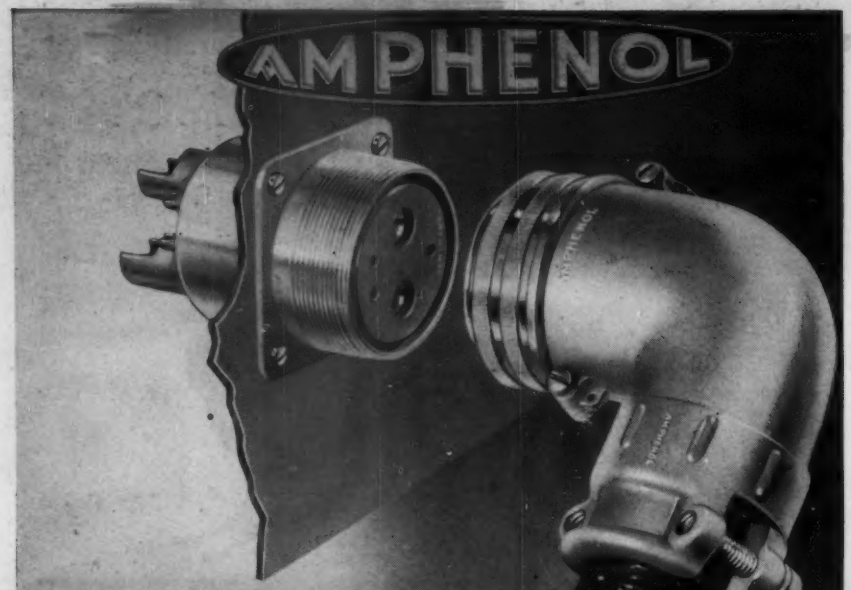

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Wherever industrial electronic equipment is sectionalized, Amphenol AN connectors serve with efficiency and economy to provide quick connection and easy disconnect for servicing or movement.

They save money by permitting associated wiring for one or many circuits to be prefabricated, thus electronic devices may be tested at the factory and instantly connected for use on arrival. This greatly simplifies installation and servicing procedures.

Available in five major shell designs, each of which accommodates over 200 styles of contact inserts, Amphenol AN connectors handle voltages up to 22,000, amperages up to 200. Types with pressure-proof, explosion-proof or moisture-proof housings also are available, as are standard elements for thermocouples.

The complete new Amphenol "AN" catalog is just off the press. A note on your letterhead will bring a copy immediately.

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AMPHENOL

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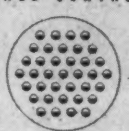
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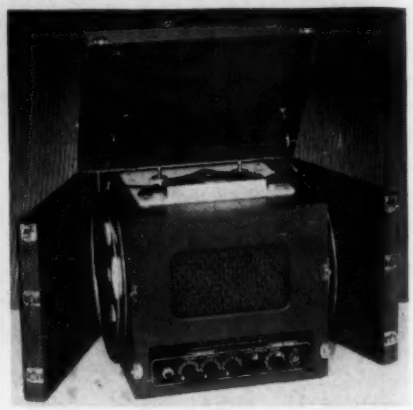
A typical example of outstanding Amphenol design:— All Amphenol solder pockets face in one direction—easy to set in a fixture—easy to solder—will not twist or turn—ideal for low-cost, efficient production. Only one of a dozen important features.

into a 50-ohm load. The attenuator is calibrated in c-w or peak pulse power or voltage into a 50-ohm load. Pulse rate is 40 to 4,000 cycles. Details of performance are available.

Dual-Channel Recorder

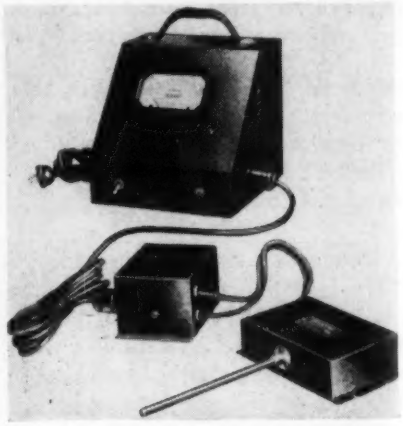
AMPLIFIER CORP. OF AMERICA, 398-7 Broadway, New York 13, N. Y. Model 910-B Twin-Trax magnetic tape recorder gives four continuous hours of recording and playback at 7½ inches per second. Two sound tracks are recorded on a single tape,



one in one direction and the other in the reverse. Frequency response is essentially flat from 40 to 10,000 cps.

Vacuum Indicator

GEORGE E. FREDERICKS CO., Bethayres, Pa. The Televac Model I vacuum indicating meter has a scale calibrated directly in the range from 1 to 1,000 microns. A voltage stabilizer mounted within the portable meter case eliminates errors



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- Max. inverse peak voltage 360
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- Dimensions: 4-1/16" x 1-1/16" x 5/32"
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Kotron's metallic rectifying elements are mounted in one plane. Plates cannot contribute heat to each other. Result—Cooler Operation . . . longer life . . . increased circuit efficiency. Wafer-thin Kotron saves space, mounts easier.

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DC

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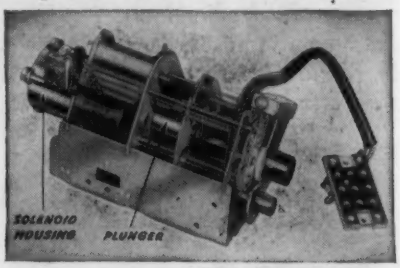

PHOTO COURTESY MOTOROLA INC.

DC 44 Silicone Grease permanently lubricates the plunger-solenoid contact surfaces in this Motorola Auto Radio push-button tuner.

Actual performance is the only true measure of a lubricant's quality. That is why more and more manufacturers are specifying Dow Corning Silicone Greases for their lubrication problems. Their tests show that longer lubrication life, greater oxidation resistance, elimination of gumming, and indifference to temperature extremes are all characteristic of the silicone greases.

Motorola Inc. of Chicago had a lubrication problem in their auto radio push-button tuner. The tuning is accomplished by a solenoid and plunger with a dash-pot action between the two for smoother operation. A thin film of the lubricant selected had to be permanent and maintain its consistency over the operating temperature range from −20° to 160°F. to give the dash-pot action.

Their engineers tested many lubricants but the only one to allow satisfactory operation and still lubricate after 75,000 cycles was DC 44 Silicone Grease. It maintains the right consistency to give smooth action and permanent lubrication. Even in thin films this silicone grease does not run out or form gum.

We recommend DC 44 Silicone Grease for permanently lubricated anti-friction bearings, and for high temperature applications up to 350°F. DC 41 Silicone Grease is recommended for temperatures up to 450°F. DC 33 Silicone Grease is both a low and a high temperature grease and is recommended for use from −95° to 300°F.

If you want permanent lubrication or have high temperature or low temperature problems it will pay you to investigate Dow Corning Silicone lubricants. Write for data sheet N 7-5 or call our nearest sales office.

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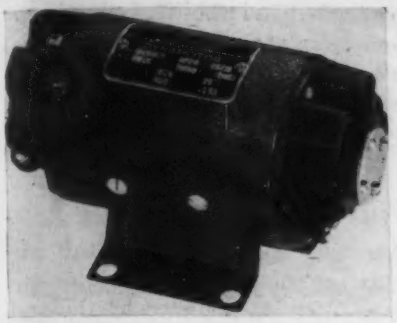
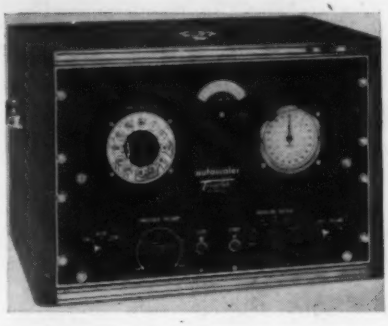


many marine and aircraft applications. It is available in a range of capacities, with power output ranging up to 80 watts continuous and 150 watts intermittent duty. The unit weighs 8¼ pounds.

Scaling Unit

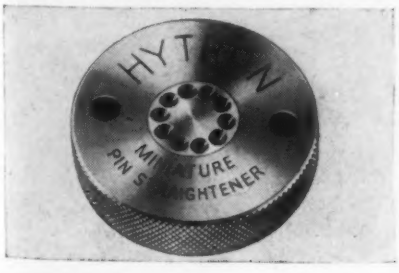
TRACERLAB INC., 55 Oliver St., Boston 10, Mass., is now manufacturing the SC-1A Autoscaler with a high voltage supply continuously variable from 500 to 2,200 volts. A time delay circuit is included. Scaling circuit and precision timer are



actuated by a pushbutton. Overall resolving time of the input amplifier and scaling circuit is about 5 microseconds. Pulse height sensitivity is approximately 250 millivolts.

Pin Straightener

HYTRON RADIO & ELECTRONICS CORP., Salem, Mass. A new miniature 9-pin straightener is now



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Small, lightweight and inconspicuous, the Turner Model L40 can be worn in the lapel, held in the palm of the hand, or concealed. Highest quality moisture sealed crystal produces high signal level. *Engineered by Turner* to give crisp, clear speech reproduction. Widely used for sales demonstrations, public address, call systems, sound re-inforcing, and recording systems. Also used in dictographic and detective work. Comfortable to wear. Alligator clip secures unit to clothing. Finished in satin chrome. Complete with 20 ft. of attached flexible cable.

Model 3H—L40

• The Turner "third hand" and L40 microphone. A special combination for mobile sound work and call systems where operator must have both hands free. Ideal for sales demonstrators. The 3H slips over the head. Holds microphone close to mouth! Adjusts to any position. Also available with microphone switch at extra cost.

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that is more active, stable and efficient than any rosin flux—yet

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ACTIVITY "Resin-Five" will solder zinc, brass, nickel silver, nickel-plate, copper and ferrous alloys.

STABILITY Under the most extreme soldering temperatures the Flux still does the soldering job.

MOBILITY The unusual activity and stability of "Resin-Five" give it complete mobility.

KESTER "RESIN-FIVE"

The most important development in Cored Solder within the last ten years. "Resin-Five" has virtually no odor even at extreme temperatures. Available in 5 core sizes; varying percentages of flux content. Diameters ranging from .010" to .250". All practical alloys.

KESTER SOLDER COMPANY

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KESTER SOLDER

A COMPLETE TECHNICAL SERVICE

Any soldering problems? Consult our Technical Department. No obligation to you.

available. It is built of aluminum and stainless steel. Designed primarily for radio servicemen, it should find utility in any laboratory.

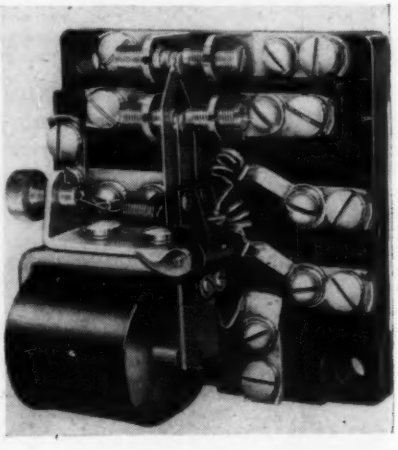
Filter Selector

AEROVOX CORP., New Bedford, Mass. Choice of proper interference filter is simplified by the analyzer that can be varied to simulate all types of stock filters manufactured by the company.

Knob setting designations are calibrated in terms of these types. Optimum arrangement can then be made after it is determined by means of the analyzer.

Sensitive Relay

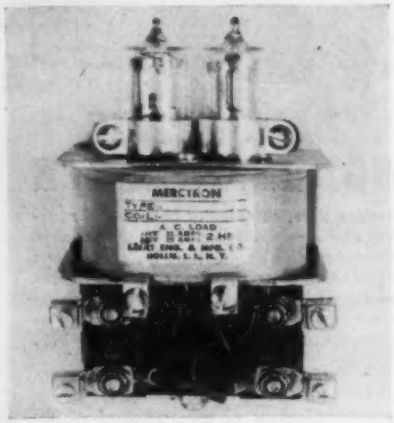
ALLIED CONTROL CO., INC., Dept. S, 2 East End Ave., New York 23, N. Y. Type BK relay, designed for high sensitivity, has a d-c coil rating up to 32 volts at 24 milliwatts and an a-c coil rating of 220 volts



at 0.240 volt-ampere. Contact rating is 1 amp at 48 v d-c. It is supplied in single or double pole, normally open or normally closed contact arrangements, also double throw.

Two-Pole Relay

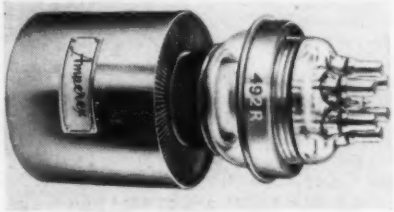
EBERT ENGINEERING AND MFG. CO., 185–09 Jamaica Ave., Hollis 7, L. I., N. Y., announces a 2-pole normally-open or normally-closed mercury relay for loads up to 25 amps breaking both sides of the line, also



motor loads up to 3 h-p at 230 volts a-c. Overall dimensions are 5 in. long, 3 in. wide and 2 in. high.

High-Frequency Triodes

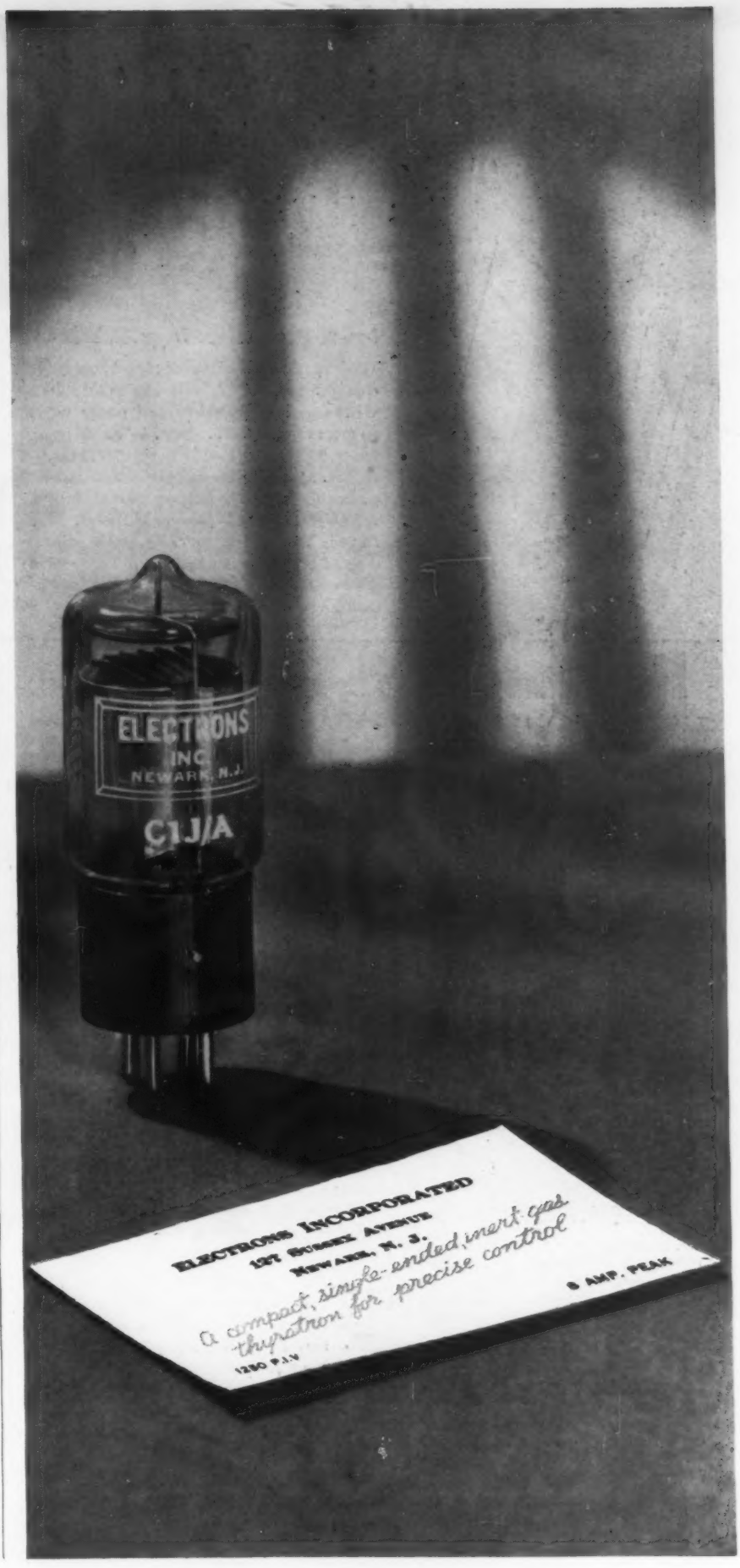
AMPEREX ELECTRONIC CORP., 79 Washington St., Brooklyn, N. Y., announce the 492 and 492-R h-f water-cooled and air-cooled triode amplifier and oscillator tubes having a 5-kw plate dissipation. The grid of each is mounted to a ring seal by an unperforated section of



copper cone which forms a shield between filament and anode, and makes the tube suitable for grounded- grid h-f circuits.

Intrusion Alarm

EL-TRONICS, INC., 2647 North Howard St., Philadelphia 33, Pa. Model



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FOR COIL WINDING

Inside Perimeters from .592" to 19"

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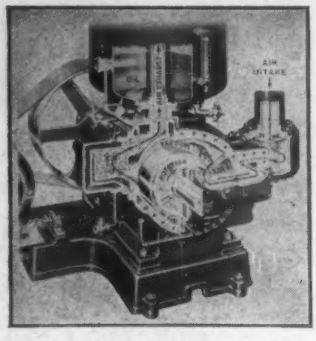
Paramount PAPER TUBE CORP.

616 LAFAYETTE ST., FORT WAYNE 2, IND.

Manufacturers of Paper Tubing for the Electrical Industry

Unique Design of Single Stage Pump Produces High Vacuum Faster, More Efficiently and Safely



The pump has only 2 moving parts — rotor and slide valve, always completely sealed in pump cylinder. As rotor turns, slide valve acts as piston forcing all air out of cylinder through discharge valve and lubricator above it, creating a constant vacuum behind the slide valve piston.

The combination of mechanical inlet slide valve, automatic exhaust valve, and rotary pump with rocker oil seals on slide valve, account for the unusually high vacuum and volumetric efficiency in this single stage pump.

for

ELECTRONICS AND LAMPS

Vacuum exhausting at low pressures of lamp bulbs, fluorescent tubes, radio, television and electronic tubes, X-ray tubes, photo-electric cells, etc.

ELECTRICAL PRODUCTS

High vacuum impregnation of coil windings to give greater strength; dehydration and impregnation of molded or compressed graphite parts; deairing, drying and impregnating insulating paper, cable, motor windings; dehydrating insulating oil; filling condensers.

ADVANTAGES

- Top Vacuum — to 2 microns
- High Speed Evacuation
- Noiseless • Vibrationless
- Low Power Consumption
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- Capacities to 845 c.f.m.

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BEACH-RUSS *TYPE RP* **VACUUM PUMPS**

FASTER, SIMPLER

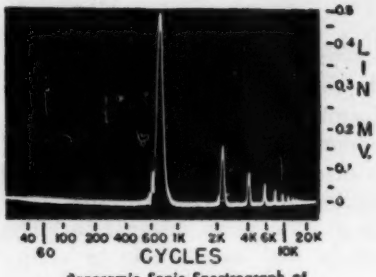
AUDIO ANALYSIS

with Model AP-1

PANORAMIC SONIC ANALYZER

Reduce time, complexity and cost of making audio measurements with the unusual advantages offered by the Panoramic Sonic Analyzer. By resolving a complex audio wave into a spectrograph showing the frequency distribution and voltage amplitude of the components, Model AP-1 . . .

• Eliminates slow point-by-point frequency checks • Provides a quick overall view of the audio spectrum • Enables determination of changes in waveform content while parameters are varied • Furnishes simple presentations for production line testing.



Panoramic Sonic Spectrograph of 750 cps square wave.

Use Model AP-1 for analyzing . . .
• Harmonics • Intermodulation • Vibration • Noise • Acoustics • Materials

Features . . . Continuous scanning from 40-20,000 cps in one second • Wide input voltage range • Linear and log voltage scale • Closely logarithmic frequency scale • Built-in voltage and frequency calibrator • Simple operation.

WRITE for detailed specs, price and delivery.

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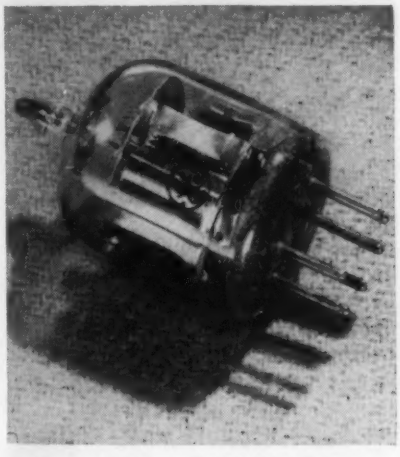
HS-5 alarm detects intrusion by change in antenna capacitance upon approach of a person. It also detects fire by means of a heat detector that operates at about 160 F. Slow capacitance changes owing to changing meteorological conditions will not affect the device.

Midget Thyratron

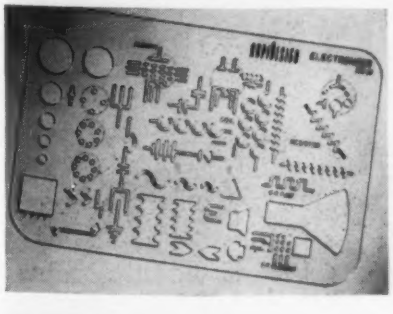
GENERAL ELECTRIC CO., Schenectady, N. Y. Type GL-5663 midget thyratron designed to maintain low



control grid and shield grid currents is inert-gas filled. Peak forward and inverse voltage ratings are 500 volts. Average anode current is 20 ma.

Symbol Tracer

RAPIDESIGN, INC., P. O. Box 592, Glendale, Calif., announces the new



Increased production permits PICKERING *to announce . . .*

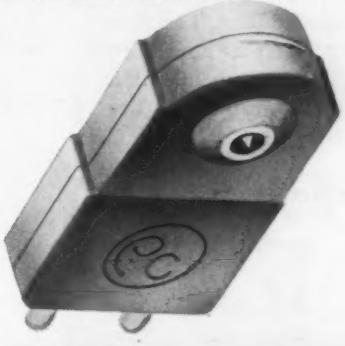
NEW · LOW · PRICES

PICKERING reproducers have always been built to the highest standards of the critical listener willing to pay a premium for excellence in record reproduction.

The growing demand for Pickering quality and the resulting increase in production have made possible substantial price reductions.

Revised manufacturing techniques have enabled us to actually improve quality and lower prices at the same time.

We take great pleasure in giving our customers the benefit of lower production costs.



Model S-120M
with .0027" Sapphire Stylus
Former List Price—$25.00
Now $16.50

Model D-120M
with .0025" Diamond Stylus
Former List Price—$60.00
Now $41.50

NEW... to the line of Pickering Cartridge Reproducers is the Model D-140S for the new long playing, MICROGROOVE type disc recordings. The D-140S has a diamond stylus of .001" radius, tracks with a pressure of 5 grams and, like all Pickering Cartridges, incorporates all of the known requirements for perfect tracking, minimum record and stylus wear, and distortion-free reproduction.

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If you use pins for vacuum tubes, adapters, fluorescent lamps, plugs, or electrical equipment of any kind, the chances are you'll save time, money and rejections by using these super-smooth, *seamless,* patented Radio Pins. They are available in a wide variety of styles and sizes, with staking end either closed or open. For a quotation, simply send a sketch, sample or description and state the quantity you need.

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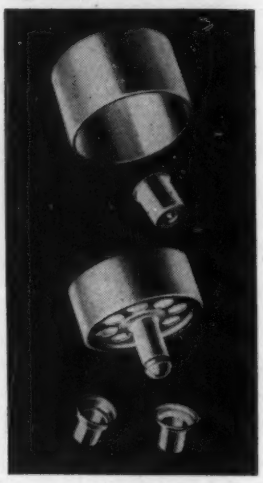
In addition to Radio Pins, we produce large quantities of top caps, base shells and adapter shells for vacuum tubes; also a wide variety of other metal products including deep drawn shells and cups, blanks and stampings, ferrules, grommets, washers, vents, fasteners—and, for almost every manufacturing requirement, the world's largest assortment of eyelets. 47429



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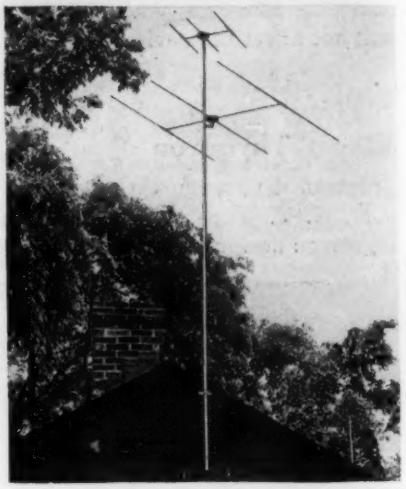
High-Gain T-V Antennas

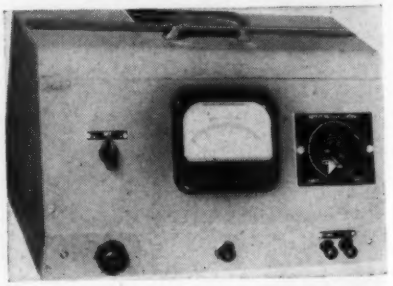
THE WORKSHOP ASSOCIATES; INC., 66 Needham St., Newton Highlands 61, Mass., has developed eight different high-gain antenna arrays for television and f-m. Each is mounted



on a single mast and designed for reception of all channels operating in a particular area. Elements are constructed of half-inch aluminum tubing. More arrays can be added to the installation as additional stations go on the air.

Low-Current Power Supply

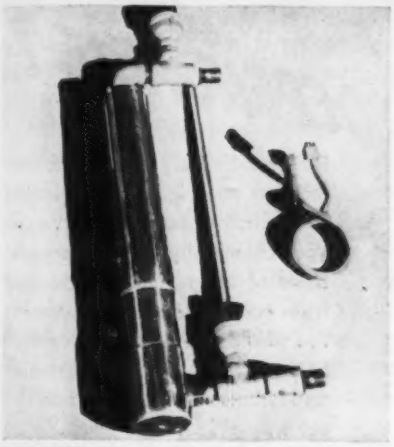
BETA ELECTRONICS CO., 1762 Third Ave., New York 29, N. Y. Model 251 regulated low-current power supply is used for currents below 10 milliamperes at voltages up to 500 volts d-c. Output voltage is continuously variable, up to 500, either positive or negative with



respect to ground; and it will change less than 0.5 percent at any setting for line voltage variations from 95 to 135 volts.

Calorimeters

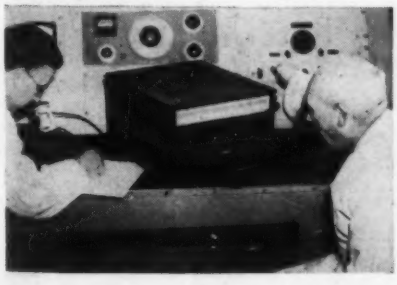
R. A. WHITEMAN, 630 N. Wisner Ave., Park Ridge, Ill. The types IHC-20 (illustrated) and IHC-50 calorimeters measure and check the power output of induction heating units. They permit measurements



from low values to 20 kw and 50 kw respectively. Each is available in either magnetic or nonmagnetic steel.

Light-Beam Wattmeter

GENERAL ELECTRIC CO., Schenectady 5, N. Y., has developed a new portable light-beam wattmeter giving readings in the low wattage, low power factor ranges for frequencies



of 25 to 3,000 cycles. It can be used as an instrument calibrator and in laboratory production testing.

Actuator

PHILLIPS CONTROL CORP., 612 N. Michigan Ave., Chicago 11, Ill. The 51A actuator features a frame of

What does a RELAY relay?
An Electrical Relay, whatever its style or type, responds to a changing condition in one electrical circuit to cause a change in another electrical circuit.
Wherever electrical energy is used as a controlling agent, SIGNAL ENGINEERING Relays can be applied in a wide variety of uses.
Perhaps you have an electronic circuit where a change in voltage or current requires the switching of several other circuits. The SENSITIVE MULTIPLE CONTACT PLUG-TYPE RELAY, illustrated at right, is designed to meet just such a condition and offers up to 6 pole, double throw, with a 20 point plug. A.C. or D.C. Ask for Bulletin 50-6.
OR
A keying circuit or pulsing circuit where rapid response and low current drain are required characteristics. The SERIES 10 AND SERIES 20 RELAYS are fast, sensitive, shockproof and are adaptable to many contact arrangements. Bulletin KR1-6.
OR
The need for a small, rugged, POWER RELAY, double pole, double throw, without pigtails, for operation of bells, horns, lamps, small motors, etc. Write for Catalog 6-6.
OR
An application requiring a high frequency COAXIAL CABLE RELAY, with correctly designed, low loss circuit, available with A.C. or D.C. actuating coils. Bulletin CR1-6.
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½ WATT INDUCTIVE

MAX. RES: .01 to 7,500 ohm (331 Alloy)
.01 to 4,000 ohm (Nichrome)
.01 to 1,250 ohm (Manganin)

BODY SIZE: ⅝" lg. by 3/16" diam.
TOLERANCE: STANDARD 1%

TYPES WL and WLA

1 WATT INDUCTIVE

MAX. RES: .01 to 15,000 ohm (331 Alloy)
.01 to 8,000 ohm (Nichrome)
.01 to 2,500 ohm (Manganin)

BODY SIZE: 1" lg. by 3/16" diam.
TOLERANCE: STANDARD 1%

Can be supplied non-inductive with one-half indicated maximum resistance.

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IN-RES-CO WL series resistors were designed to meet increasing demands for a compact resistor of high accuracy priced for general use. They meet the most critical requirements—close tolerance, ability to withstand overload, long life. Write today for catalog describing the full line of quality IN-RES-CO resistors.

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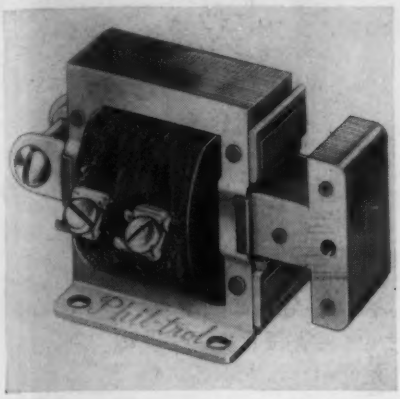
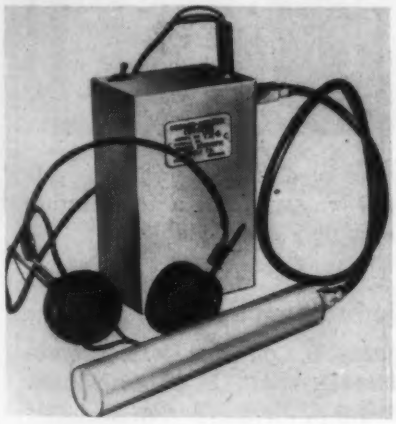


bonded silicon steel laminations and a T-shaped laminated plunger adaptable for both push and pull operations. It is available for continuous duty on 115 volts, 60 cycles, with a maximum stroke of one inch. Approximate pull is 2 pounds at ¾ inch, 4.2 pounds at ¼-inch stroke.

Geiger Counter

OMAHA SCIENTIFIC SUPPLY CORP., 3623 Lake St., Omaha 4, Nebraska. The 3½-pound TX-6 Geiger counter consists of a probe, amplifier, and headphones. Gamma rays from uranium ore produce clicks in the



phones. The instrument is sensitive enough to detect radiation in a radium dial watch.

Photorelays

PHOTOBELL Co., 116 Nassau St., New York 7, N. Y. Type ES-1 electric eye relay operates from 115 volts 60 cycles, and comprises a photoelectric tube, amplifier, relay and sensitivity adjustment all mounted on a 2½ x 5-inch steel chassis. Type ES-2 is similar but includes a light projector built into

New, Lighter, More Compact . . .
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- Quick response. Stabilizes varying input voltage within 1/20 second.
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- Many designs available with very low harmonic distortion of the output voltage wave at any load.
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Waltham 54, Massachusetts

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THE NEW **THYROMETER**

Integrating type scaler with ratemeter

Designed for precision measurement of radioactive samples in the research and medical laboratory.

Some of the special features include:

(1). Both scaler and ratemeter can be operated as a unit or the ratemeter can be operated as a separate unit.

(2). All operating controls are mounted on the sloping panel.

(3). The unit employs a three decade logarithmic type ratemeter.

(4). A strip chart recorder may be used to indicate the output of the ratemeter circuit.

(5). A range switch provides selection of counting ranges of one, two or three decades (100 — 1000 — 10,000 counts per second) for the recorder.

(6). The scaling circuit measures the time required to accumulate a predetermined count with a total selection of five ranges up to 16384 counts.

(7). Available for use with a choice of G-M tubes, sample stage, probes and preamplifiers.

(8). The unit may be mounted on an undercarriage as illustrated for utility and accessibility.

(9). The ratemeter may also be furnished as a separate unit.

Write for particulars on this or other radiation measuring instruments and components.

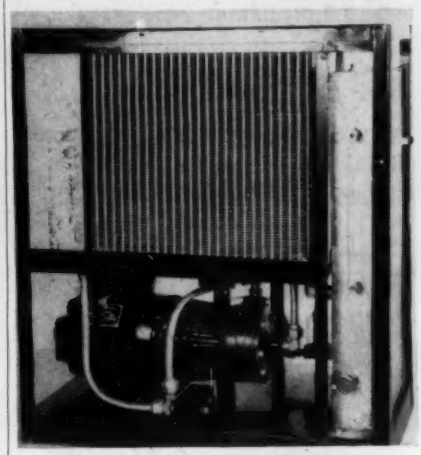
THE VICTOREEN INSTRUMENT CO.

5806 HOUGH AVE., CLEVELAND, OHIO

the chassis base. Response time is about 0.05 second, permitting use as a counting machine at speeds up to 600 counts per minute.

Heat-Transfer Unit

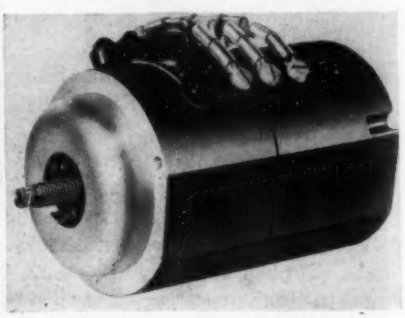
EASTERN INDUSTRIES, INC., 296 Elm St., New Haven 6, Conn. Model No. 5-H.T.U. is a new heavy duty heat-transfer unit for cooling the magnetron power tube in an induction-

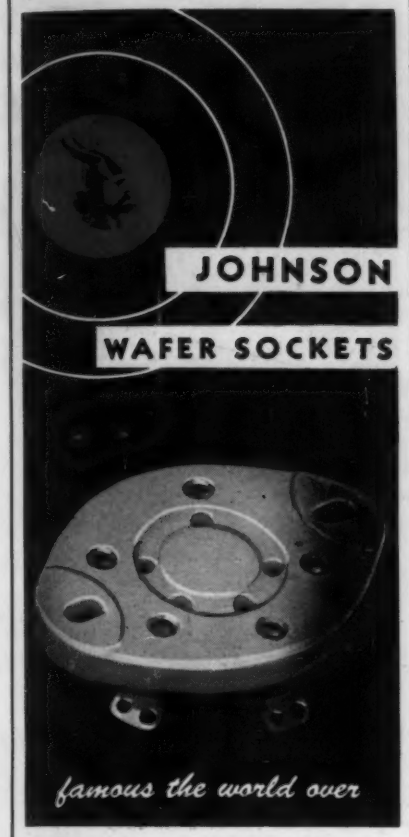


heated oven. The unit will dissipate 3,000 watts within a temperature rise of 40 F above ambient.

Engine Synchronizer

SQUARE D CO., KOLLSMAN INSTRUMENT DIVISION, 80-08 45th Ave., Elmhurst, N. Y. A new 28-ounce synchronous differential contains two synchronous motors and a mechanical differential. Used in synchronizing engines, it serves as an





Exacting users prefer JOHNSON wafer sockets because they are insulated with grade L4 steatite or better, top and sides are glazed, the underside is impregnated against moisture. Contacts are brass with steel springs, cadmium plated and are mounted against phenolic washers in molded recesses to prevent movement. Rivets are countersunk and mounting holes bossed to permit sub-panel mounting. Locating grooves facilitate tube insertion.

Illustrated above is the 122-225, a 5 pin socket which can be used with such tubes as the 807.

Additional Types

122-224, 4 pin, for tubes such as the 812 or T40

122-226, 6 pin, for tubes such as the T21

122-227, 7 pin medium, for tubes such as the RK34

122-217, 7 pin small, for tubes such as the 6A7

122-228, octal, for tubes such as the 6L6 and 815

Also available are Giant wafer sockets for transmitting tubes, of 5 or 7 pin bases, sockets incorporating a base shield, and Super Jumbo 4 pin base sockets.

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Your coil windings are perfectly mated for long and useful life when the bases are

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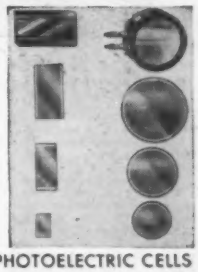

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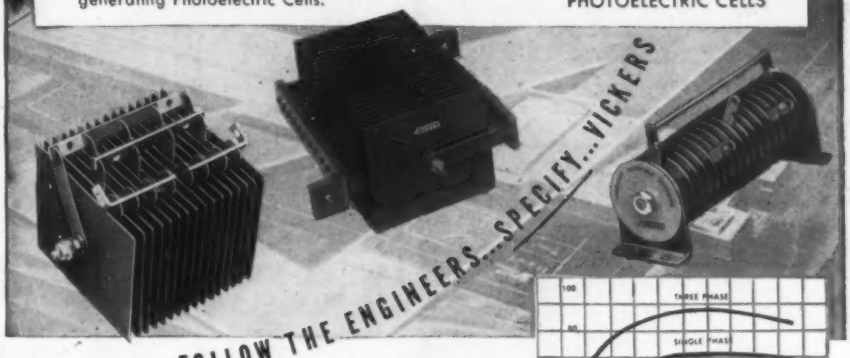

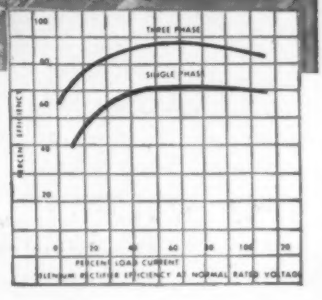

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VICKERS INC.

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RF POWER AMPLIFIER

This "500" watt, RF power amplifier unit may be used as the basis of a high power amateur band transmitter or as a means for increasing the power output of an existing transmitter. As shipped from the factory, the No. 90881 RF power amplifier is wired for use with the popular RCA or G.E. "812" type tubes, but adequate instructions are furnished for re-adjusting for operation with such other popular amateur style transmitting tubes as Taylor TZ40, Eimac 35T, etc. The amplifier is of unusually sturdy mechanical construction, on a 10½" relay rack panel. The panel contains the grid and plate tank tuning capacitor dials, as well as the grid and plate current milliammeters. Plug-in inductors are available for operation on 10, 20, 40 or 80 meter amateur bands, from stock, as well as special coils to order for commercial frequencies. The standard Millen No. 90800 exciter unit is an ideal driver for the new No. 90881 RF power amplifier.

JAMES MILLEN MFG. CO., INC.

MAIN OFFICE AND FACTORY
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intermediary regulating device of engine control equipment. It may also be used as a torque-producing half-speed synchroscope. The unit operates from a three-phase source over a frequency range of 15 to 60 cycles with an input voltage of 0.007 times the frequency in cycles per minute.

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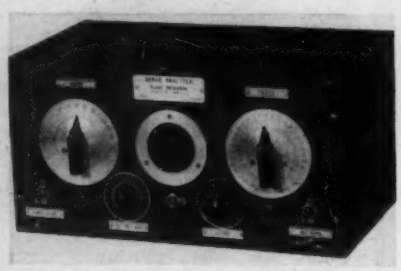
FLIGHT RESEARCH ENGINEERING CORP., P.O. Box 1-F, Richmond 1, Va. The Servo Analyzer is used as an aid in developing and testing servos and automatic control systems employing 400 cycle error measuring devices such as Selsyns



or E type pickoffs. Frequency response and transfer function may be obtained over an input range of from 1 to 60 cps.

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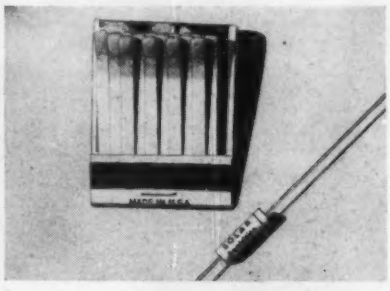
SOLAR MFG. CORP., 1445 Hudson Blvd., North Bergen, N. J. Type TST capacitors are 3/16 inch in diameter and ⅝ inch long, sealed



against humidity effects. Details are given in a new catalog bulletin.

High-Speed Counters

POTTER INSTRUMENT CO., INC., 136-56 Roosevelt Ave., Flushing, N. Y., has developed a new system for measuring frequencies from 0 to 1.6 mc with accuracies

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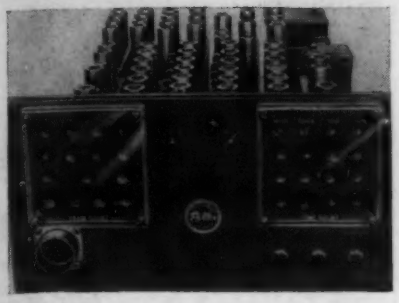
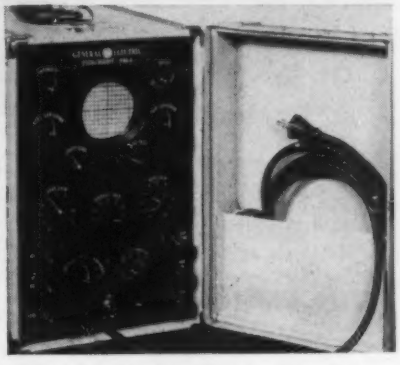


of one part in ten million or greater. Basic units of the system are two high-speed electronic counters, a crystal oscillator and an electronic switch. The instrument shown, a Doppler frequency chronograph, measures unknown frequencies of 50 to 200 kc using the new system.

Industrial Scope

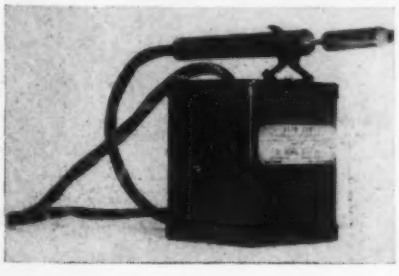
GENERAL ELECTRIC CO., Syracuse, N. Y. Industrial oscilloscope type YNA-4 is intended primarily for servicing such equipments as resistance welders, motor control cir-



cuits, and photoelectric circuits. A three-inch tube is employed with pushpull d-c amplifiers. Horizontal sweeps range from 10 cps to 20 kc.

Low-Voltage Soldering Iron

JET THERMAL DEVICE CO., 2873-86th St., Brooklyn, New York. The Slim Jim soldering iron can be used on automobile storage battery or socket



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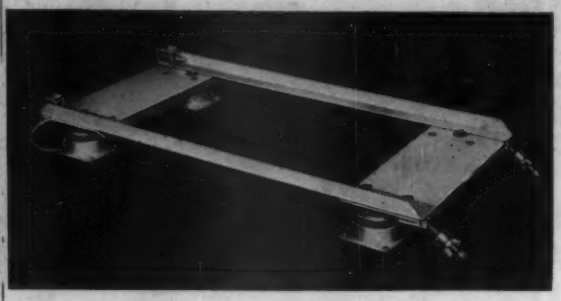

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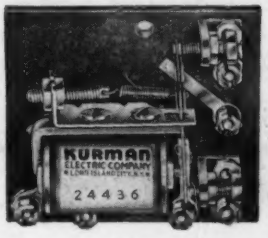

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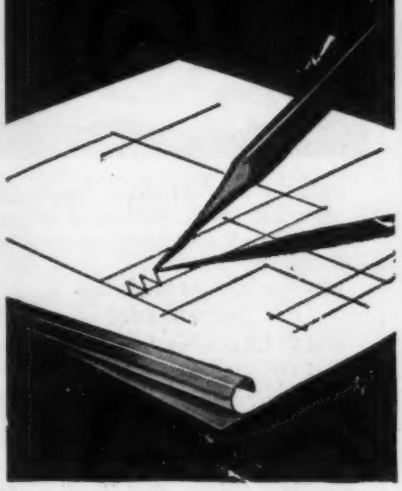

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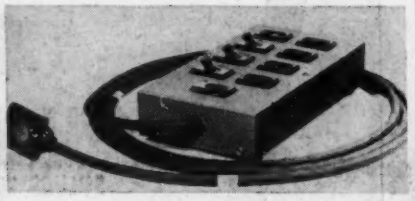
Fractional Motor

BACH ELECTRICAL CORP., Bridgeport, Conn., announces a new fractional 110-volt 60-cycle a-c motor. It is Fiberglas insulated and has

cast-aluminum rotors. Further information is available from the company.

Control Panel

EWART AND KOCH, 15 Brattle St., Cambridge 38, Mass. The switch and receptacle unit illustrated is equipped with eight feet of rubber



cord with fused plug. A neon pilot lamp shows when the unit is plugged in.

Plane Radio

RADIO CORP. OF AMERICA, Camden, N. J. A new compact, plane-radio transceiver is now available. The One-Sixteen weighs only nine pounds and fits into the instrument panel. A single selector switch tunes in any broadcast program on the standard band or any frequency from 200 to 400 kc. A special

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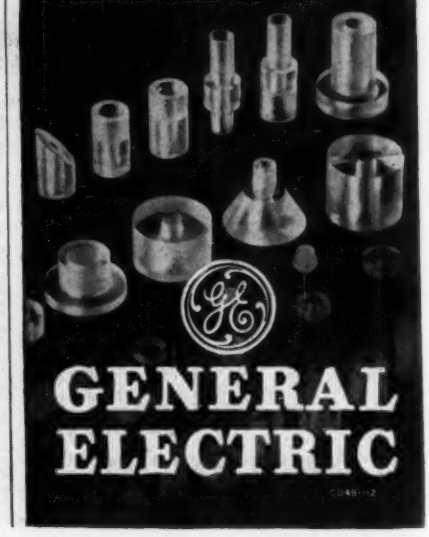

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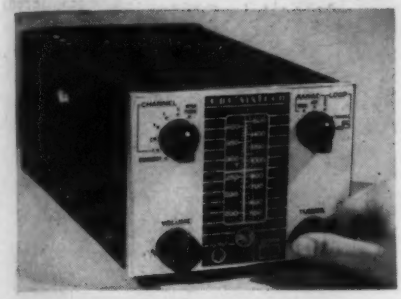
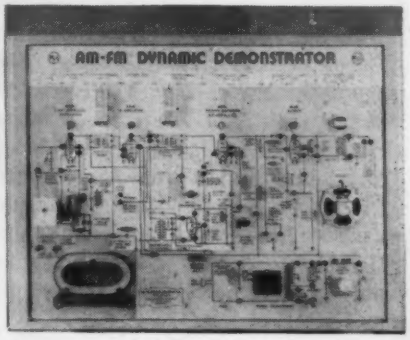


marker indicates standard tower frequency of 278 kc.

Radio Instruction

RADIO CORP. OF AMERICA, Camden, N. J. The Dynamic Demonstrator is an f-m and a-m six-tube radio receiver with its circuits and components laid out on a panel 45 × 33 inches for purposes of study. It is designed to simplify the teaching of radio theory, operation and



maintenance. The unit will operate on a-m from a signal generator as well as an antenna. The f-m i-f will operate from a sweep generator.

Audio Units

FAIRCHILD CAMERA & INSTRUMENT CORP., 88–06 Van Wyck Blvd., Jamaica 1, N. Y. Audio units from microphone preamplifier to rack frame are available in numerous combinations that are flexible to the current needs of the amplifier system. Basic component is Unit 620 power amplifier with a frequency response from 20 to 20,000 cycles.

Appliance Tester

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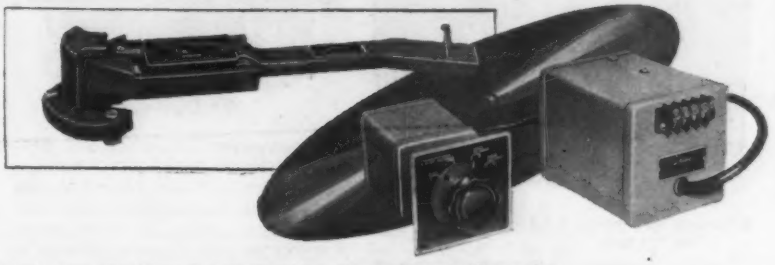

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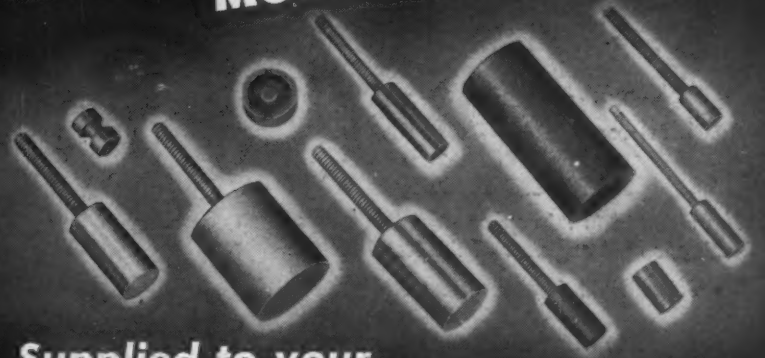

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Literature

Fabrics Bulletin. The Duplan Corp., Industrial Division, 512 Seventh Ave., New York, N. Y. Many technical facts for a large number of standard weaves of Fiberglas and Nylon fabrics are given in a recent bulletin. A wide range of industrial applications is illustrated and described, together with details of their properties.

Connector Catalog. Cannon Electric Development Co., Humboldt St. and Ave. 33, Los Angeles 31, Calif. The C-47 edition of Cannon Plugs contains 32 pages in 3 colors, covering the thirteen major type series of multi-contact electric connectors. Prices are given on all except the AN, K, and DPD series.

Motor Catalogs. Gleason-Avery Inc., Auburn, N. Y. Two new catalog sheets have been recently released. The first deals with both synchronous and nonsynchronous instrument and timing motors. The second covers the series 500 gear motors. Both are well illustrated and give complete specifications.

Automatic Computing System. Eckert-Mauchly Computer Corp., Broad and Spring Garden Sts., Philadelphia 23, Pa. An 8-page

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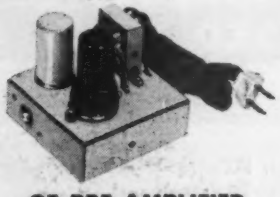

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booklet shows the chief features of the Univac (Universal Automatic Computer), which is the central component of an electronic system by which many types of information can be processed with speed and economy. Operation includes the use of a newly developed magnetic tape recording system.

Microwave Test Equipment. Polytechnic Research and Development Co., Inc., 66 Court St., Brooklyn 2, N. Y. New sheets are now available for the company's catalog of test equipment. Included are waveguide terminations, variable flap attenuators, slide screw tuners, and directional couplers.

All-Channel Antenna. The Workshop Associates, Inc., 66 Needham St., Newton Highlands 61, Mass. A catalog sheet and assembly instructions are available for the new indoor television and f-m antenna that is constructed of corrugated board covered with aluminum foil. The antenna is designed to be mounted in an attic.

Transmitting Tubes. Sylvania Electric Products, Inc., Emporium, Pa. Characteristics on more than a score of types with rated plate dissipation ranging from 20 to 175 watts are given in a six-page bulletin.

Motor Control. J. B. Lewis & Co., 3324 Main St., Hartford 5, Conn. Bulletin 105 points out the features of a new wide range, adjustable speed, motor control employing two electronic tubes.

A-M and F-M Tuner. Browning Laboratories, Inc., Winchester, Mass., has issued catalog sheet 8415 describing the characteristics of an a-m and f-m tuning unit with f-m sensitivity of 10 microvolts for 30 db noise reduction. Curves of its performance are also available.

Crystal Pickup. Electro-Voice, Inc., Buchanan, Mich. The Series 12 Torque Drive crystal pickup cartridge was developed to provide light weight coupling of crystal to record groove. Fourteen outstand-

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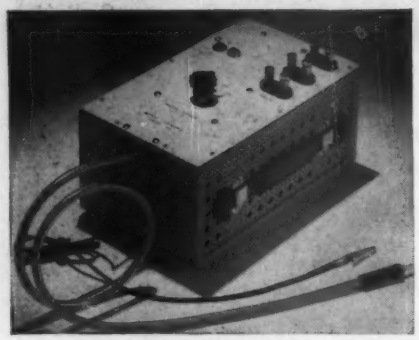

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ing features are treated in bulletin 141.

Standards Index. American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. The recently issued 240-page index to ASTM standards as of December 1947 will be furnished without charge on written request. Items are listed under appropriate key words according to particular subjects.

Electronic Glassware. T. C. Wheaton Co., Millville, N. J. A complete line of electronic glassware, particularly glass-to-steel hermetic terminals in various shapes and sizes, is covered in a recent bulletin.

Industrial and Laboratory Devices. Airmec Laboratories Ltd., 19 Charterhouse St., London, E. C. 1, England. Descriptive leaflets are available on the d-c ionization voltage tester type 732, the d-c oscilloscope type 723, and the electromechanical counter type 737.

Oscillography Equipment. Allen B. DuMont Laboratories, Inc., 1000 Main Ave., Clifton, N. J., has issued an informative pamphlet covering c-r tubes, oscillographs, allied equipment, and accessories. It may be obtained by request on business letterhead.

Laboratory Catalog. Fisher Scientific Co., 717 Forbes St., Pittsburgh, Pa. and Eimer & Amend, 635 Greenwich St., New York 14, N. Y. A 40-page profusely illustrated book pictures 268 laboratory innovations and describes more than 300 equipment items that have been developed to aid laboratory work.

Chemical Products. General Electric Co., 1 Plastics Ave., Pittsfield, Mass. An 18-page illustrated booklet CDP-576 describes briefly a wide range of chemical products such as plastics, resins and insulating materials, metallurgical products and compounds. A technical bulletin is available on each product described.

Tube Data. Radio Corp. of America, Harrison, N. J. A four-page technical bulletin gives complete data on the 6BA7 and 12BA7 pentagrid converters which are in-

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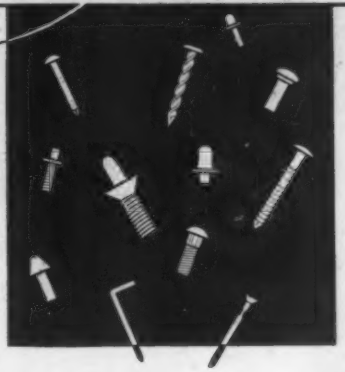

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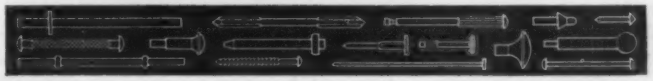

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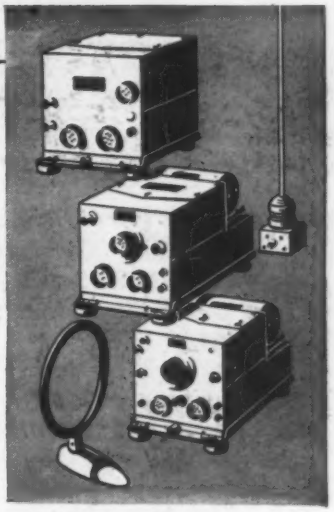

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Motors Guide. Allis-Chalmers Mfg. Co., Milwaukee 1, Wis. A 12-page loose-leaf perforated booklet offers a quick reference to data on a variety of general purpose motors. It is well illustrated and gives specifications and applications.

Snap Switches. The Acro Electric Co., 1305 Superior Ave., Cleveland 14, Ohio. A recent catalog describes, complete with mechanical drawings and operating characteristics, many types of snap-action switches with the patented rolling spring construction.

Silicone Products. General Electric Co., Pittsfield, Mass. A 30-page illustrated bulletin CDR-57 describes in detail the new silicone resins, oils, greases, water repellents, and rubber together with their many industrial uses. Charts and tables are included for handy reference.

Isotope Apparatus. Tracerlab Inc., 55 Oliver St., Boston 10, Mass. A 40-page booklet shows a variety of scalers, counters, timers, sample changers, and radiation survey meters. Chief features, uses, and specifications for each are given. Also included are descriptions of radioassay accessories.

Annual NBS Report. Department of Commerce, U. S. Government Printing Office, Washington, D.C. The 1947 report of the National Bureau of Standards involves five types of activities: research and development; test, calibration and standard samples; commodity standards and codes and specifications; advisory services; and cooperative activities. A complete table of contents is given.

Resistance Measurement. James G. Biddle Co., 1316 Arch St., Philadelphia 7, Pa. The 12-page bulletin 24–25 contains photographs, wiring diagrams and charts showing various aspects of low-resistance testing and its application. It features the Ducter ohmmeter which measures resistance down to 0.000001 ohm.

Radio Heater. Rediffusion Ltd., Broomhill Road, Wandsworth, London, S. W. 18, England. A re-

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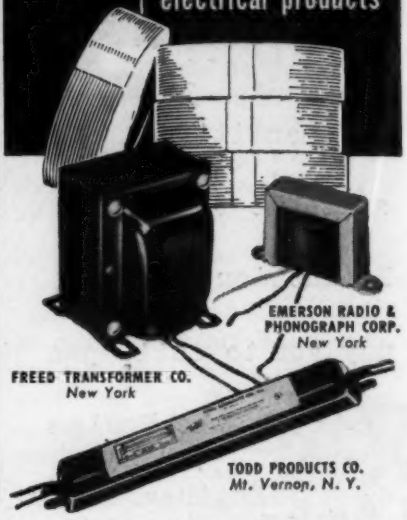

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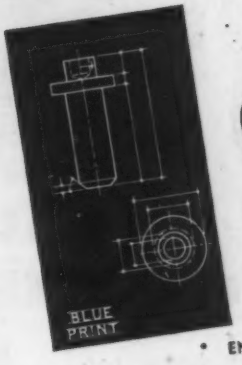

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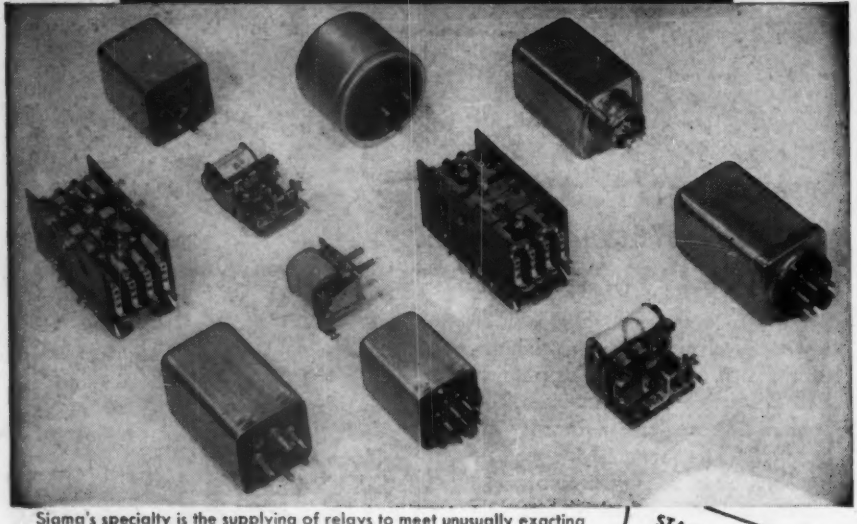

Sigma's specialty is the supplying of relays to meet unusually exacting requirements. Such success as we enjoy is due as much to willingness to study applications in detail as to basically good relay designs.

You are urged to take advantage of this in submitting your problem, by stating particulars of purpose and function, permitting us to see the relay as part of a complete system.

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cent leaflet pictures and technically describes the model RH. 24 Redifon industrial radio heater with an output of over 350 watts. The unit is specifically designed for dielectric heating applications and features a single oscillator valve of the latest repairable silica-envelope type.

Paper Tubulars. Cornell-Dubilier Electric Corp., South Plainfield, N. J. Descriptive bulletin NB116 covers the Grey Tiger paper tubulars which are Vikane impregnated and feature outstanding performance over a temperature range of −55 C to +100 C. These capacitors are primarily designed for use in automobile radios and other high-temperature applications.

Recording Catalog. Gorrell & Gorrell, Haworth, N. J. Bulletin G-100 is a condensed catalog briefly outlining features, functions and general construction of several types of instruments for timing, control, and graphic recording. Complete details and typical applications are given in individual bulletins.

Microphones. Electro-Voice, Inc., Buchanan, Mich. Bulletin 103 illustrates and describes in four pages many models of microphones, stands and accessories now available.

Internal Defect Locator. Sperry Products, Inc., 1505 Willow Ave., Hoboken, N. J. Operation and application of the new portable, lightweight type SR05 supersonic reflectoscope is described in bulletin 3001. This nondestructive testing instrument is used for locating internal defects in metals and other materials.

Precision Equipment. R.T.S. Electronics Ltd., King St., Exeter, England. The model EA11 single-channel cro, model EA20 resistance-capacitance bridge and EA36 signal tracer are fully treated in a 12-page, board-covered booklet.

Fractional H-P Motors. Alliance Mfg. Co., Alliance, Ohio. Various types and sizes of electric motors rated from less than 1/400th h-p to 1/20th h-p are described and illustrated in a four-page folder. Applications are given.

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For use in computing and analyzing devices; generation of low frequency saw tooth and sine waves; controls for radio and radar equipment; position indicators; servomechanisms; electro medical instruments, measuring devices—telemetering; gun fire control where 360° rotation, high precision and low noise levels are essential.

The type RL14MS sinusoidal potentiometer is illustrated. It is wound to a total resistance of 35,400 ohms and provides two voltages proportional to the sine and cosine of the shaft angle. It will generate a sine wave true within ±.6%. Overall dimensions are 4⅜" diameter x 4 11/32 long plus shaft extension ¼" diameter x 1¼" long.

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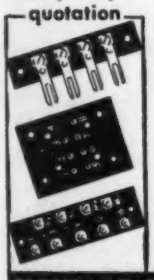

Several pages of Jones Catalog No. 16 illustrate standard and special panels we are constantly producing. Latest special equipment enables us promptly to produce practically any panel required. Send print or description for prices, without obligation. Hundreds of standard terminal strips also listed. Send for Catalog with engineering drawings and data.

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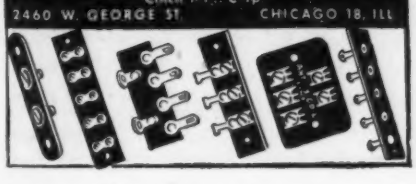
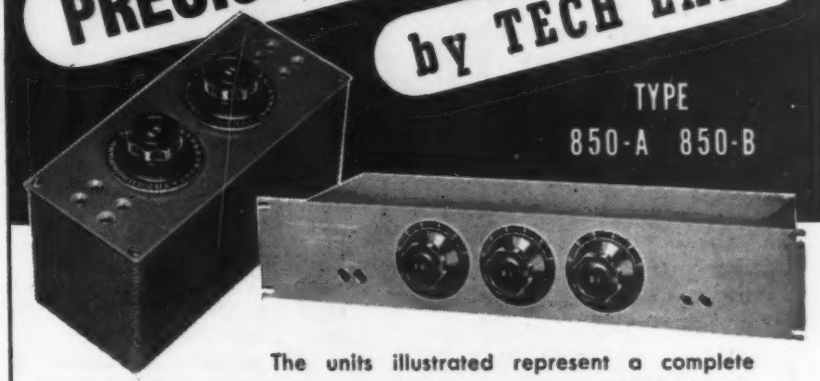


NEW...IMPROVED PRECISION ATTENUATORS by TECH LABS

TYPE 850-A 850-B



The units illustrated represent a complete redesign of our older precision attenuators for laboratory standards. Flat for all frequencies in the audio range. Reasonably flat to 200 k.c. up to 70 db.

Bulletin sent on request.

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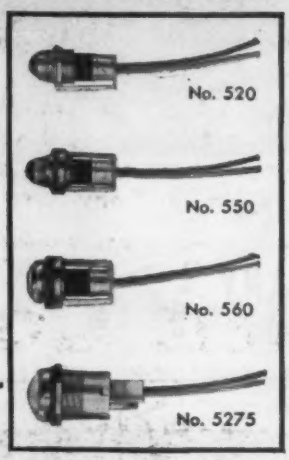

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- No terminals to short circuit
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- Highly economical to install
- Meets UL requirements

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programs are currently being broadcast in Leningrad twice a week, and are expected to be increased to four times a week soon. The Leningrad center also plans to have in operation by autumn a portable television transmitter.

During the past two years The Moscow Radio Club organized two cycles of 15 lectures each dealing with the principles of television and how to build a television receiver. Under the aegis of the club's television section 400 amateurs made their own television receivers and are now viewing regular programs broadcast by the Moscow Tele-Center.

Rural Industrial Radio

A SPECIAL INDUSTRIAL radio service was recently proposed by the FCC to make radio-communication available to persons engaged in commercial or industrial operations which are predominantly rural in nature. Under this category would be included farming, ranching, irrigation, mining and construction activities.

Also covered by the proposed special service would be those engaged in commercial and industrial operations involving hazard to life and property where use of radio would decrease such hazards, those engaged in operations reacting directly upon public welfare or safety, and maintenance and repair services directly involving public health or well-being.

URSI-IRE Meeting

A SECOND joint meeting of the American Section, International Scientific Radio Union, and the Institute of Radio Engineers will be held in Washington on Thursday, Friday, and Saturday, October 7, 8, and 9, 1948.

The program will, as usual, be devoted to the more fundamental and scientific aspects of radio and electronics. The program of titles and abstracts will be available in booklet form for distribution before the meeting. Anyone wishing to submit papers for presentation at this meeting should send in title and a 100-word abstract before

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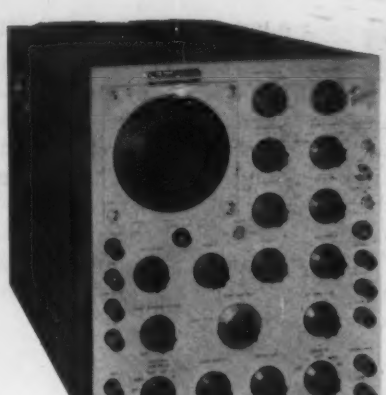

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The Tektronix Type 511 is a portable wide band oscilloscope providing facilities formerly available only in very expensive, cumbersome instruments.

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- Continuously variable .1 second to 1 microsecond (10 cm. deflection).
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- Choice of triggered, recurrent or single sweeps at all speeds.
- Triggers on sine waves to 10 mc. or pulses over .05 microsecond.
- Any 20% of sweep may be expanded 5 times.
- DC coupled PP amplifier for external sweep input.

VERTICAL DEFLECTION SYSTEM

- Amplifier Bandwidth 10 mc., 1 stage; 8 mc., 2 stages.
- Rise Time .04 microsec., 1 stage; .05 microsec., 2 stages.
- Maximum Sensitivity .27 V/cm. (Peak to Peak).
- Input Impedance Direct 1 meg., 40 mmf.; Probe 10 meg., 11 mmf.

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- Calibrating voltage 0-1, 0-10, 0-100 volts, 60 cycles.
- CRT 5CP1A, 5CP7A or 5CP11A operating at 3 kv.
- Direct connection to all plates from side panel.
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The Model 204A Regulated Power Supply will provide from 0-500 volts of well regulated and well filtered D.C. The output voltage is continuously variable without switching and either positive or negative side may be grounded.

SPECIFICATIONS:

OUTPUT VOLTAGE
High Voltage: 0-500 Volts D.C. continuously variable (Without switching).
Current: 300 Ma.
Low A.C. Voltage: 6.3 Volts A.C. at 6 amps. center-tapped, unregulated

REGULATION
Within 1% for voltage between 30-500 volts, from no load to full load.
Within 1% for line voltage variations from 105 to 125 volts at full load current for any voltage between 30-500 volts and within 2% at 10 volts.

HUM VOLTAGE
Within 10 Millivolts at any voltage or load within ratings.

LINE INPUT
105-125 Volts A.C. 50-60 cycles.

OUTPUT TERMINATIONS
High and low voltage outputs available from front and rear of unit. Positive or negative terminal of high voltage output may be grounded as desired.

Detailed specifications will be forwarded upon request without obligation.

E/M

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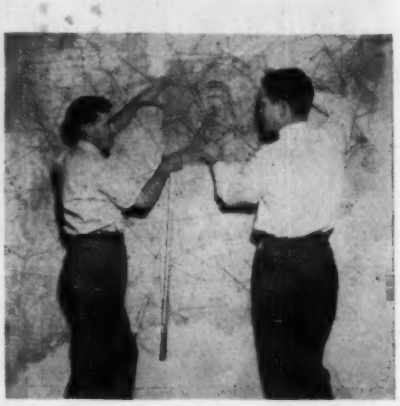
August 20 to Dr. Newbern Smith, Secretary, American Section, URSI, National Bureau of Standards, Washington 25, D. C.

San Francisco Audio Society

ON JUNE 22 in San Francisco's NBC Building the first organizing meeting for formation of a San Francisco Section of the Audio Engineering Society was held. About thirty audio specialists attended and established by acclamation a temporary chairman, I. R. Ganic of Audiophone, Oakland, Calif. There was also a talk and demonstration of the Ampex tape recorder by Myron Stolaroff.

Television Reallocation

HEARINGS WERE HELD in Washington, D. C. recently at which the FCC proposed a nation-wide reallocation of the twelve television channels. A 10 x 16ft. map of the U. S., on which interference conditions are graphically portrayed, was prepared by Allen B. DuMont Laboratories, Inc., for the occasion.



Dr. Thomas T. Goldsmith (right), head of DuMont research division and an assistant, Robert Wakeman, with map of U. S. showing FCC's proposed allocation

The DuMont proposal includes first the correcting of some serious spacings in the proposed FCC allocation plan and secondly the addition of a few further channels beyond the present twelve.

Channel Numbers to Stay

WAYNE COY, chairman of the FCC, recently announced that the Commission is not considering a renum-

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Industrial Electronics Reference Book

By Electronics Engineers of the Westinghouse Electric Corp.

This book was compiled to answer the need for complete and clear information on the application and design of industrial electronic equipment. Written by a group of engineers, each an expert in his particular branch of electronics, the *Industrial Electronics Reference Book* contains the most recent information on the subject. The material is directed at the practicing engineer. Its aim is to give him a better understanding of the scope and limitations of electronic apparatus as it is applied to industrial processes.

Contents Include:

Physical Background of Industrial Electronics; Electron Emission; Control of Free Electrons; Electrical Conduction in Gases; Vacuum Tubes; Gas Tubes; Photoelectric Devices; Industrial X-Ray Tubes; Cathode-Ray Tubes; Ultraviolet Radiators; Circuit Elements; Tuned Circuits and Filters; Transformers; Vacuum Tubes as Circuit Elements; Electronic Motor Control; Industrial Photoelectric Control; Care and Maintenance of Electronic Apparatus.

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bering of the present 12 television channels. In a letter to the executive vice-president of the RMA he stated that neither the report and order deleting Channel No. 1, nor the proposed rule revising the allocation of television channels contemplates changing the numbering of the remaining 12 television channels.

Army Tests Transistors

A RECENT Bell Laboratories development, the transistor (see p 68, this issue), gives promise of having great military value for communications equipment. Exhaustive tests are being undertaken by the Signal Corps to gather complete data on the device's characteristics and its reaction to shock, vibration and extremes of climate.

The transistor, a new crystal triode, is important to the army because, having no filament, it requires no heating current to amplify voltages. In portable communications equipment, such as the walkie-talkie and the handy-talkie, a large part of the weight and bulk consists of batteries for heating tube filaments. Transistors would greatly reduce the ground soldier's load.

Signal Corps engineers caution that there is little conclusive data on the new crystal triode's performance. They believe it will be useful where low power is involved but expect to continue to rely on the vacuum tube for high-power equipment.

Utilities Radio Committee

AT A RECENT meeting attended by twenty-two power utilities representatives from all over the country, the National Committee for Utilities Radio was organized in Chicago. It will be a successor committee to the group formerly known as Committee 4 of Panel 13, RTPB.

The first item of business which the new organization undertook was the formulation of comments to be forwarded to the FCC on their new proposal for the reallocation of frequencies in the various bands and on the proposed new rules under which the licensees represented by this committee are to operate. Empha-

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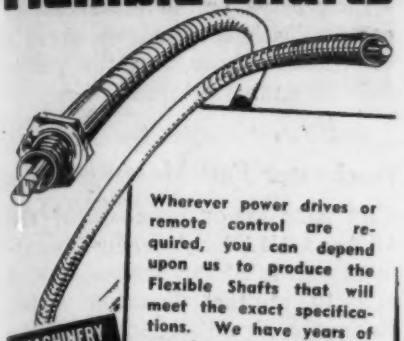

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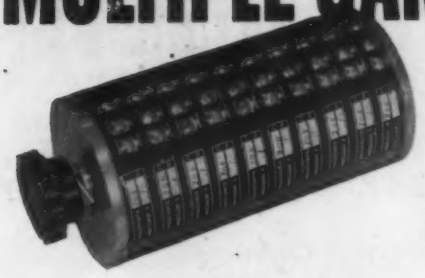
MULTIPLE GANGING



FOR AN ANALOG COMPUTER

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10-Gang Linear Potentiometer

The Problem: To raise the function A to various powers up to A^{10}. Space, weight and driving torque to be held to a minimum; accuracy to be better than ± .5%.

The Solution: This Fairchild type 748 ganged precision linear potentiometer with output accuracy ± .1%.* Torque is reduced to a minimal 5.5 ounce-inches for the entire 10-gang assembly . . . wiper contacts are in permanent correct alignment on the windings . . . backlash is completely eliminated—all by mounting the units directly on a single shaft without couplings.

*Isolating amplifiers between each consecutive cascaded voltage divider eliminate loading errors.

For complete data on these instruments, precision-engineered for over a million cycles of operation, address Dept. I, 88-06 Van Wyck Boulevard, Jamaica 1, New York.

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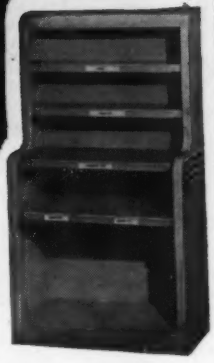

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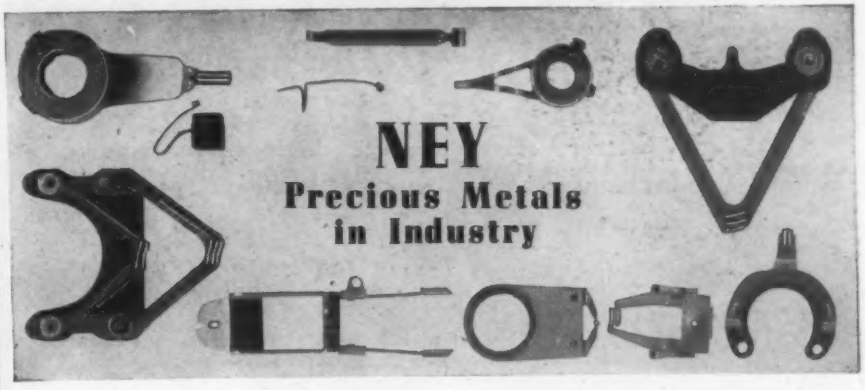

A marked increase in service life and performance of brush contacts is made possible by using minute quantities of an appropriate precious metal alloy for the actual contact. The photograph above shows brush arms and contacts used in a variety of typical applications. Note the small amount of precious metal needed to assure superior service.

Ney also offers industrial users a wide range of precious metal alloys for many specialized applications as well as gold solders and fine resistance wires (bare or enameled). Details on request.

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sis was placed on the importance of communications in this service, its emergency nature, and the public safety features involved.

Rochester Fall Meeting

THE MEETING OF members of the IRE and RMA Engineering Department scheduled for November 8, 9 and 10 at the Sheraton Hotel, Rochester, New York, will mark the 20th anniversary of the Rochester Fall Meeting. Officers of the committee in charge, in addition to Virgil Graham of Sylvania, chairman, include Howard A. Brown, vice-chairman and H. J. Klumb, treasurer, both with Rochester Gas and Electric Corp., and O. L. Angevine of the Rochester Engineering Society, secretary.

BUSINESS NEWS

RAYMOND ROSEN ENGINEERING PRODUCTS, INC. is a recently formed subsidiary of Raymond Rosen & Co. for handling specialized phases of sound, communication and electronic engineering and development work.

HEWLETT-PACKARD CO., Palo Alto, Calif., manufacturers of precision electronic measuring instruments,

Interior of new Hewlett-Packard plant

has completed construction of new plant facilities totalling 20,000 sq. ft.

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Our research and development now permit us to offer manufacturers genuine diamond needles hitherto unobtainable.

Radius and angle are positive gem finish, insuring gem contact in record groove, and assuring a minimum of record wear.

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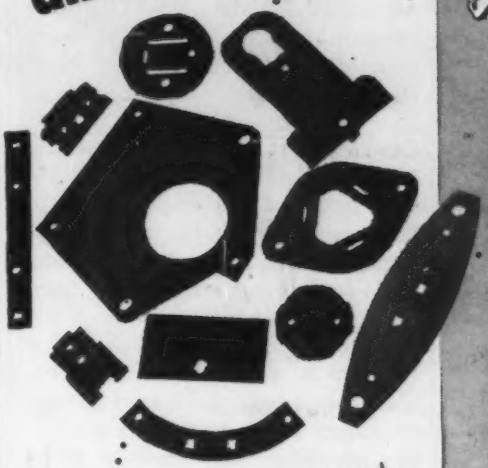
Baer* can supply your vulcanized and phenol fibre fabrications



* Baer fibre is versatile . . . can be stamped, punched, drilled, tapped, milled, sheared, sawed and shaved to specification.

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When you use these tough, lightweight and inexpensive parts, you build their many advantages *into your own product.* Fabricated to order, BAER FIBRE washers, special shapes, terminal boards, and other parts are accurately and uniformly produced to specification in any quantity. Selection of grades by physical and electrical qualities, permits application to a wide range of operating conditions and requirements. Investigate now!

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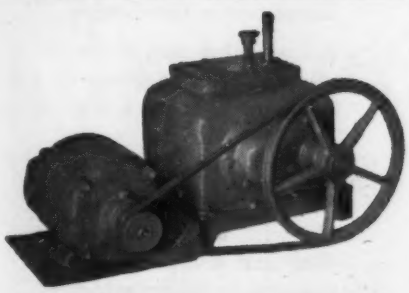

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This high vacuum pump is widely known and used extensively in the manufacture of electric lamps, radio tubes, fluorescent lamps, for laboratory work and for many industrial applications where high vacuum, plus rapid exhausting are essential requirements in processes of manufacturing.

In free air capacities ranging from 1 cubic foot to 50 cubic feet per minute.

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Operates quietly. Prompt deliveries

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Model MM252
Model MM272

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Micro-Match models available for operation at 500 KC to 250 MCS, and power levels of 2 to 50,000 watts.

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Transmission line impedance 52 (MM252) or 72 (MM272) ohms
Wattmeter Scales 0 to 10, 100 and 1000 watts
Range of Power measurement 1/10 to 1000 watts
Power range for SWR measurement 2-1000 watts
Reflection Coefficient less than ½ db.
Power loss through instrument less than 3/10 db.
Connectors Amphenol type 82-64; also available 83-1R

Write for complete details on these and other MicroMatch SWR and RF power monitors.

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It gives essential data about S.S.White Resistors, including construction, characteristics, dimensions, etc. Copy with price list on request.

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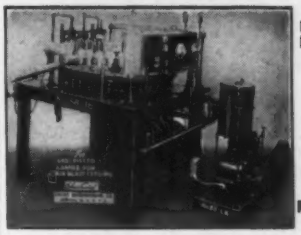

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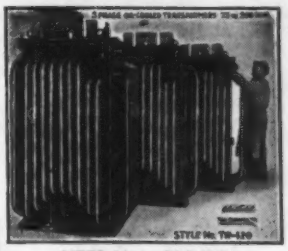

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SERVICING THE MODERN CAR RADIO by A. L. Hurlbut

Second edition, 702 pages, 8½ x 11, 222 illus., over 500 circuit diagrams...$7.50

Here—written by a practical auto radio expert of 20 years' standing—is everything to help the beginner or experienced serviceman gain profitable skill in the fast-growing field of car radio servicing. A complete guide to the work. Book not only describes installation, testing, and repair methods fully, but also gives needed special facts of car radio circuits, differences beween car and home radio servicing problems, shop set-up and business-getting ideas, etc. And invaluable for all jobs is the big gallery of circuit diagrams on hundreds of models, old and new.

Practical facts and methods on:

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OPPORTUNITY OF A LIFETIME

for alert servicemen, says A. A. Ghirardi author of famous radio servicing books and articles

ALFRED A. GHIRARDI

"I believe SERVICING THE MODERN CAR RADIO represents an opportunity no wide awake serviceman can afford to miss. There are over 9,000,000 car radios—approximately 16 out of every 100 radio receivers in use today—a wonderful field for increasing servicing business; increasing profits, stepping ahead of competition! Good auto radio men are scarce, and this book gives you a gold mine of information you need to cash in on this profitable, fast-growing business."

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RADIO SONIC CORP., formerly Tuck Electronic Corp., has moved its research laboratory and factory to 186 Union Ave., New Rochelle, N. Y.

AMERICAN BROADCASTING COMPANY recently installed an RCA 80-ft antenna for WJZ-TV atop the Hotel Pierre, New York City.

GENERAL ELECTRIC CO., Syracuse, N. Y., designed and installed a 2½-watt f-m transmitter for Syracuse University. Preliminary FCC approval of such noncommercial, low-cost f-m broadcasting has been given.

HOWARD W. SAMS & CO., INC., Indianapolis, Ind., publishers of the Photofact Folders, began in set No. 38 a presentation of television principles for radio service technicians. The entire series will be included in consecutive sets.

THE PERMANENTE METALS CORP. will reactivate its plant at Permanente, Calif., to handle the facilities of an entire German aluminum foil mill purchased from the Foreign Liquidation Commission.

FIELDEN ELECTRONICS INC., of Huntington Station, N. Y., was recently incorporated and is closely associated with Fielden (Electronics) Ltd., of Manchester, England, manufacturers of the Drimeter, a device for giving continuous indication of moisture content for the textile industry.

PERSONNEL

M. J. KELLY, executive vice-president of Bell Telephone Laboratories, has been named chairman of the newly constituted Committee on Navigation which will work closely with the Air Navigation Development Board.

FRIEDA B. HENNOCK recently became the FCC's first woman commissioner.

CLARENCE A. LOVELL was co-recipient of the 1948 Potts Medal of the Franklin Institute for combined

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saves money

ECONOMY in building television sets is *important* and the General Electric Focus Coil points the way to *important* savings in manufacturing.

1. The G-E Focus Coil requires less current—permitting the use of lower-priced power supplies.
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A *complete* high fidelity radio system at a reasonable price.

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Newly developed direct-reading instrument simplifies measurements of variations in speed of phonograph turntables, wire recorders, motion picture projectors and similar recording or reproducing mechanisms.
The Furst Model 115-R "Wow-Meter" is suitable for both laboratory and production application and eliminates complex test set-ups.

The instrument incorporates an additional amplifier stage so that a direct-inking recorder may be connected for qualitative analysis of speed variations. Send for Bulletin 115.

Frequency Response: ½ to 120 cycles

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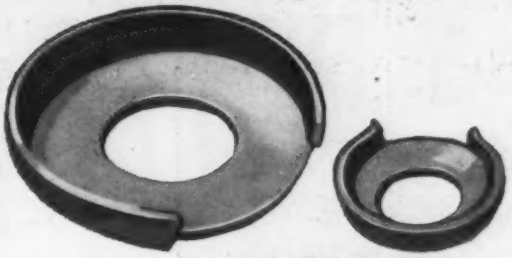

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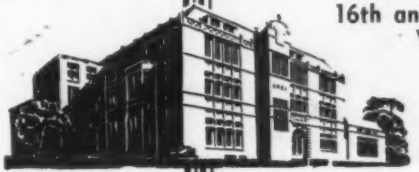

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Reveals basic facts heretofore unknown!

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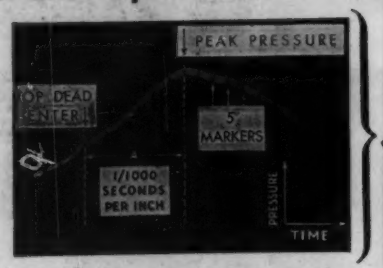
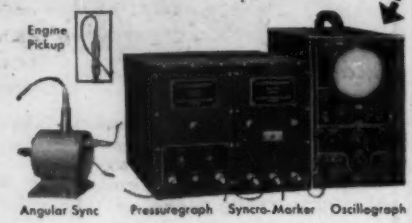


Know your pressure variations and you know how to increase engine, pump or pressure line efficiency.



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Whatever your special problems consultation with our engineers is cordially invited.

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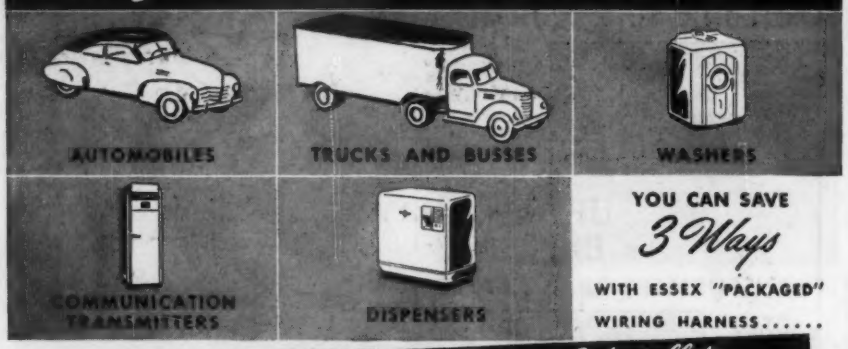

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Essex *One-Source* service handles the intricate job of producing lighting, ignition and control harness assemblies *custom-built* to your exact specifications and *complete* with all manual and electrical control devices for quick, efficient installation.

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contributions to the theoretical and practical design of the electrical gun director.

DAVID B. PARKINSON was co-recipient with Dr. C. A. Lovell of the 1948 Potts Medal of the Franklin Institute.

JAN A. RAJCHMAN, with RCA since 1936 and chiefly responsible for the development of the electron multiplier, recently received the 1948 Levy Medal of The Franklin Institute in recognition of a paper entitled "The Electron Mechanics of Induction Acceleration", jointly authored with W. H. Cherry.

J. A. Rajchman

W. H. Cherry

WILLIAM H. CHERRY, co-author of the above-mentioned paper, was the co-recipient of the Levy Medal. He has been engaged in research for RCA since 1941 and is at present working in the RCA television group.

WILLIAM BALDERSTON, formerly executive vice-president, has been elected president of Philco Corporation. Between 1944 and 1946 he directed the company's reconversion to civilian production.

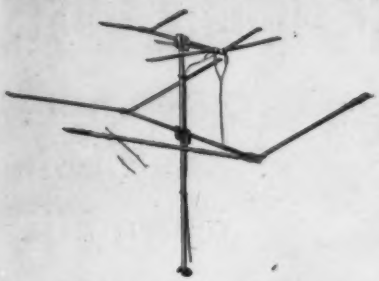
PAUL H. WENDEL, formerly associate editor of *Radio News* and business manager of *Radio Maintenance*, has joined the Photofact staff of Howard W. Sams & Co., Inc., Indianapolis, Ind.

DAN DROMMERHAUSEN, senior engineer with Hoffman Radio Corp., Los Angeles, has become manager of the service department.

STUART BALLANTINE (deceased) was recently awarded posthumously the Armstrong Medal for outstanding contributions to the art. One of his many works was development, on a purely mathematical basis, of

PREMAX

Lo-Hi Television Antenna



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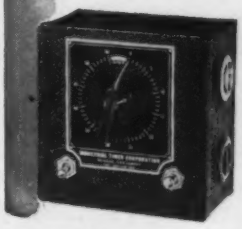

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Edison Model 501 Thermal Relay *PROTECTS* Electronic Tube Cathodes

Delays application of plate voltage. Timing varies with line voltage, as does cathode heating time.

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Hermetic sealing excludes dust and corrosion. Arc-quenching atmosphere minimizes contact pitting or transfer. Contacts actuated silently and positively by an electric heater. Insensitive to transients or momentary power interruptions. Operates in any position. A simple, inexpensive relay for continuous operation.

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Delay: 5 sec. to 8 min. Preset as required.	**Ambient Range:** —60° C to +60° C
Contacts: SPST, normally open or closed.	**Size:** 1¼" dia.; 3½" high, seated.
Contact Rating: 6 amps. at 250 volts AC/DC	**Weight:** 0.08 lb. to 0.14 lb.
Heater: 5 watts. 115 volts max. AC/DC	**Mounting:** Std. Octal or 4-prong tube base.

Write for Publication No. 3007

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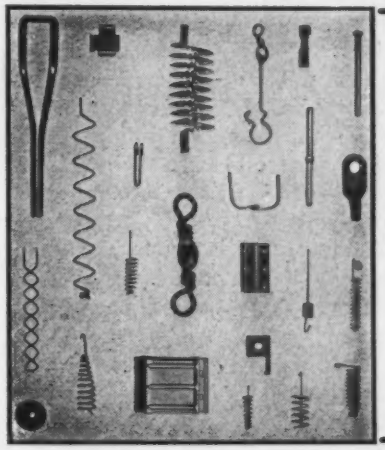

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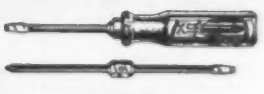

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the theory of the vertical antenna and its low-angle radiation.

DONALD K. DE NEUF is chief engineer of the Rural Radio Network's sixth f-m station, WVBN, at Turin, N. Y. Like the other five (WFNF, WVFC, WVCV, WVBT, and WVCN), it is operating on a radio relay network basis. WGHF in New York City is an affiliate.

EVERETT S. LEE, chief engineer of G-E's General Engineering and Consulting Laboratory at Schenectady, has been elected president of the AIEE for 1948-49.

ALBERT J. FRIEDMAN, formerly associated with the Federal Telephone and Radio Corp. of Nutley, N. J. and the Island Electronics Co. of Freeport, N. Y., has been appointed chief antenna development engineer at J. F. D. Mfg. Co., Inc., Brooklyn, N. Y.

PAUL THOMPSON has been named chief electronic engineer of the Turner Company, Cedar Rapids, Iowa, manufacturers of microphones and electronic equipment.

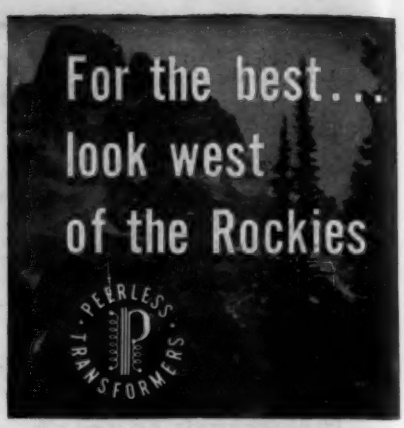
P. Thompson

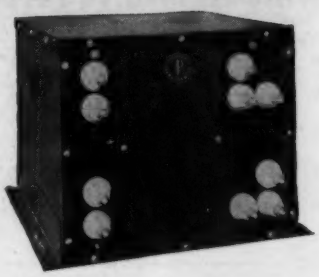
L. L. Helterline, Jr.

LEO L. HELTERLINE, JR. has been promoted from chief engineer to general manager of Sorensen and Co., Inc., Stamford, Conn. He was formerly associated with General Motors and Sylvania Electric Products Co.

WILLIAM A. BROWNE, former engineering buyer for radar development at Sylvania's Electronics Division, was recently appointed merchandising supervisor for the Radio Division of Sylvania Electric Products, Inc.

R. L. CAMPBELL has established a consulting television engineering laboratory in Boston, Mass.





when others failed, Peerless engineers successfully solved a

TOUGH PROBLEM

Illustrated above is a modulation transformer, extremely difficult to design and manufacture. Other manufacturers failed to meet the customer's requirements. Peerless surprised the customer by *more than meeting* requirements. Designed to meet C.A.A. specifications and specifically, the following electrical characteristics:

FREQUENCY RESPONSE — The frequency response of this unit is flat within 1 db from 90 cps to 12,000 cps and within .1 db from 9,000 cps to 11,000 cps for all specified loads.

DISTORTION — The audio distortion in the transformer is less than 2% for all specified frequencies and impedances and all power levels up to 250 watts.

INSERTION LOSS — The insertion loss is less than 2½% at 1,000 cps for all specified loads.

REACTANCE — The reactive value of the input impedance is less than 100% of the resistive value for any audio frequency from 90 cps to 200 cps; less than 50% from 200 cps to 1000 cps; and less than 15% from 1000 cps to 12,000 cps. These ratios obtain for all specified loads at any power level up to 250 watts.

PHASE SHIFT — The phase shift of this unit is less than 5% between 9,000 cps and 11,000 cps for all rated impedances.

LET PEERLESS HANDLE YOUR TOUGH PROBLEMS

The above clearly demonstrates that Peerless, with one of the finest and largest technical staffs, can design, engineer and manufacture transformers to meet your most difficult problems and specifications. Avoid delays that cost time and money—consult Peerless *first*.

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NEW BOOKS

Vibration and Sound

By Philip M. Morse, *Director, Brookhaven National Laboratory. McGraw-Hill Book Co., Inc., New York, N. Y.* 1948, *Second Edition*, 468 *pages*, $5.50.

This is a revision of the original book brought out in 1936. The author has continued the objective of the first edition, namely, a thorough treatment of the theory of vibration and sound for students in physics and communication engineering. In attaining these aims the author has provided an adequate and complete treatment of the mathematical foundations of conventional sound theory which forms the basis for the solution of the specific problems. Accordingly, the first part of the book is concerned with a complete mathematical treatment, with most of the detailed steps included. In the latter portion of the book, the treatment is not as complete and therefore, requires some effort to fill in the intermediate steps.

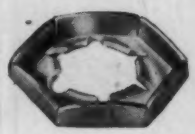
The subject matter is confined for the most part to types of vibrations that can be handled mathematically. It is not, however, a book on mathematics with sound as an excuse. Mathematics is used as a tool. Sufficient explanation is given for the most part to keep the physical concepts and significance of the formulas clear.

The use of diagrams to illustrate modes of vibrations of strings, bars, membranes, and plates is one of the outstanding and useful features of the book. In the case of membranes and plates, the figures are presented in perspective to show the shapes for the lower modes of vibration. Illustrations of this kind are useful because they give at a glance information which cannot be readily gleaned from the mathematics.

Some of the subjects not usually considered in detail in books on sound are as follows: the perturbation theory of strings with variable density, effect of motion of the end supports of a string, vibration of membranes and plates, radiation resistance of radiators of various shapes, scattering of sound from obstacles, and room acoustics.

The transient response of vibrating systems is one of the important

Slash Fastening Costs



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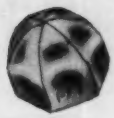

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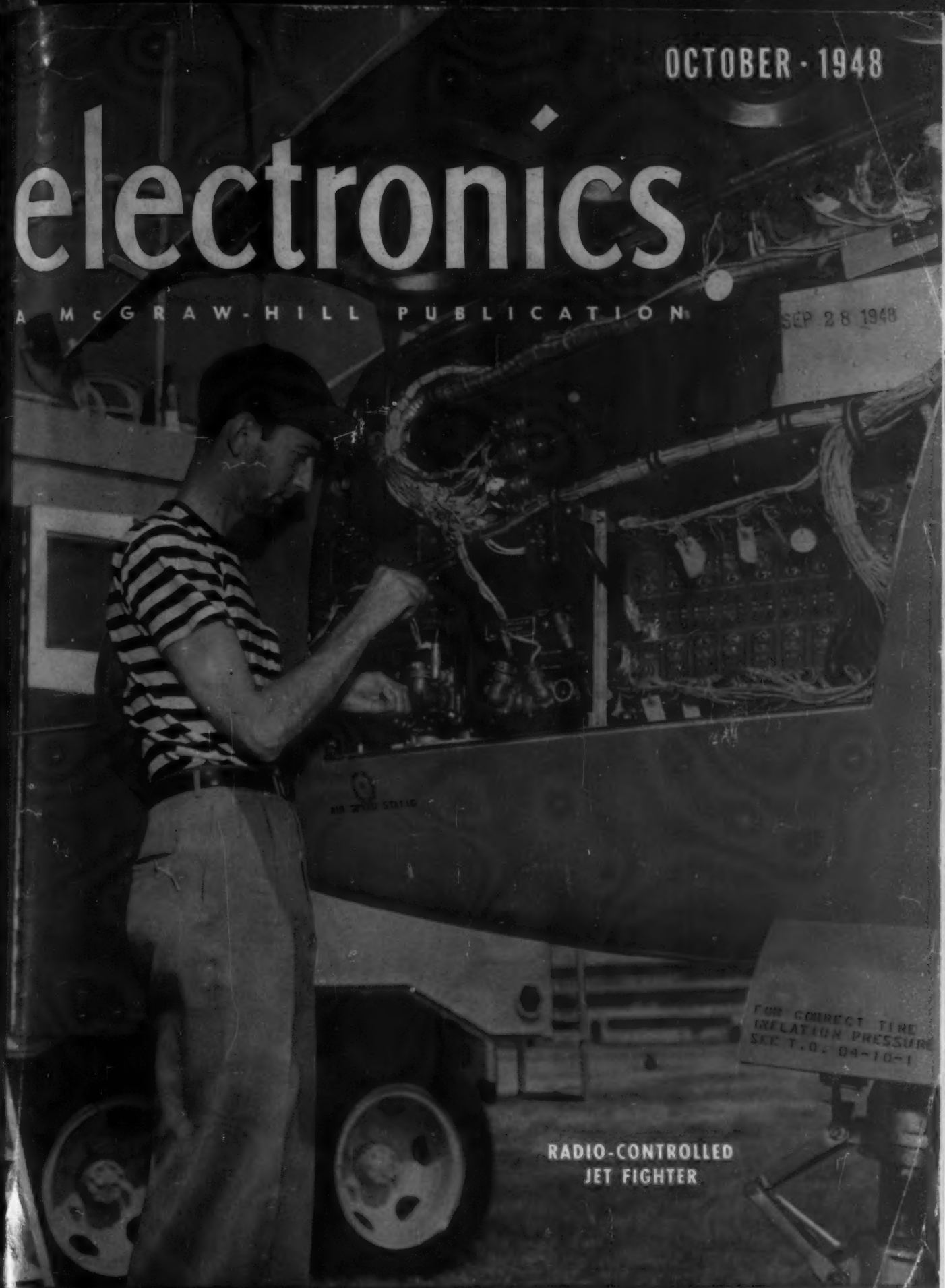

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